FINAL REPORT

PASSIVELY SCANNED STAR TELESCOPE

Contract No. NAS 1-3185

to

National Aeronautics and Space Administration
Langley Research Center

November 1965

Prepared by

HONEYWELL
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Boston, Massachusetts 02135

Rg/43176

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I
SUMMARY

This document describes a Passively Scanned Star Telescope which will determine the instantaneous spin axis attitude of a small research rocket with respect to celestial coordinates.

The work performed under Contract NAS1-3185 awarded June 1963, has resulted in the design and fabrication of a star telescope which can detect 0 to 3rd magnitude stars. The signal, received from the detected star, is coded by the reticle and processed within the photomultiplier subassembly of the telescope. The output of the P/M tube amplifier is sent to the onboard telemetering equipment in the form of a calibrated pulse train whose amplitude is proportional to the intensity of the observed star. A second output is provided to monitor excessive P/M tube anode currents. The PSST is used to provide attitude information aboard the D-61 vehicle.

The PSST flight unit, qualification unit, and spare P/M subassembly were delivered to NASA in May 1964. During simulated flight testing at Langley, a low frequency transient was detected in the amplifiers, and the units were returned to Honeywell for rework. During the recalibration of the P/M subassemblies, a sensitivity shift was noted. The power supply voltage and amplifier were rechecked and it was determined that the sensitivity shift was being caused by a gain shift in the P/M tubes. The P/M tubes were returned to the vendor for depotting and analysis, which showed that the gain of the last four dynode stages had dropped.

As a result of this analysis it was decided to purchase two new tubes. To minimize the dynode gain shifts, these tubes were burned in at a 5 microamp current for 100 hours to stabilize the gain shift prior to final calibration. One of the two tubes degraded below the specified

level and was replaced by a new P/M tube. One of the high voltage power supplies was returned to the vendor to change the output voltage to match the new tube.

A second amplifier, the telemetry amplifier, was added to the P/M subassembly at this time to monitor anode currents up to 50 microamps. The main amplifier saturates if the anode current exceeds 1 microamp (current caused by radiation from objects brighter than 0 magnitude). The flight unit and spare P/M subassembly were re-assembled and recalibrated and shipped to NASA in April and June 1965, respectively.

As an additional task, a study was made to determine a method to keep the P/M tube anode current below 5 microamperes when the PSST was looking directly at the earth during a daytime mission. Several methods were analyzed and one breadboarded and tested. During the test phase, NASA determined that a daytime launch was not practical because of launch window considerations, and the D-61 was to be launched at night. Testing of the breadboard earth shine circuit was completed and delivered as a breadboard.

II
SYSTEM DESCRIPTION

The Passively Scanned Star Telescope consists of a refracting optical system; a coded reticle; a photomultiplier tube (P/M) with high voltage power supply; and an amplifier which will process the output signal for an airborne telemetry system. In addition, the unit will also serve as a pressure seal between the payload interior and the environment of outer space.

The star telescope will be oriented perpendicular to the thrust axis of a small, spin stabilized research rocket during a free-fall trajectory. Star images in the field of view will be scanned over the coded reticle located in the focal plane, modulating the radiation received by the photomultiplier tube. The amplitudes of the signal are proportional to the spectral radiance of the scanned stars. The distance between each pulse is a function of the spin rate and orientation of the star to the vehicle coordinates. The telescope is protected by a sun shield to permit adequate shielding from the sunlight during daylight conditions.

The star telescope system can detect radiation from stars of visual magnitude 3 and brighter with a signal to noise ratio greater than 12. The output signal from the system is amplified and transmitted to earth via the on-board transmitter. When data is compiled at the ground station, the relative position and approximate photoelectric magnitude may be determined. Radiation from the earth will also be detected with which to establish the spin rate of the rocket. Comparing the star data of this flight with known star information determines the orientation of the vehicle during the free-fall trajectory.

A block diagram is shown in Figure 2.1. Radiation from a star is incident on the four lens refracting optical system which focuses the energy upon the reticle. As the vehicle rotates, the star image is swept across the reticle which in effect codes the signal according to its position on the reticle. The radiation then passes thru the field lens which forms an image of the entrance pupil upon the face of the P/M tube.

The P/M tube changes and amplifies the radiation into an electrical signal. This signal is further amplified in the output electronics which can be described most simply as a bandpass amplifier. This signal is then sent to the vehicle telemetry system. A telemetry amplifier is also connected across part of the P/M tube load resistor. This amplifier is used to monitor the P/M anode current for large pulse of anode current which would saturate the output electronics amplifier.

The high voltage power supply, which is part of the P/M subassembly, is used to provide approximately 2000 volts to the P/M tube.

A sunshield is attached to the front of the optical base casting to prohibit rays of light from the sun, earth, etc. outside the field of view from saturating the P/M tube.

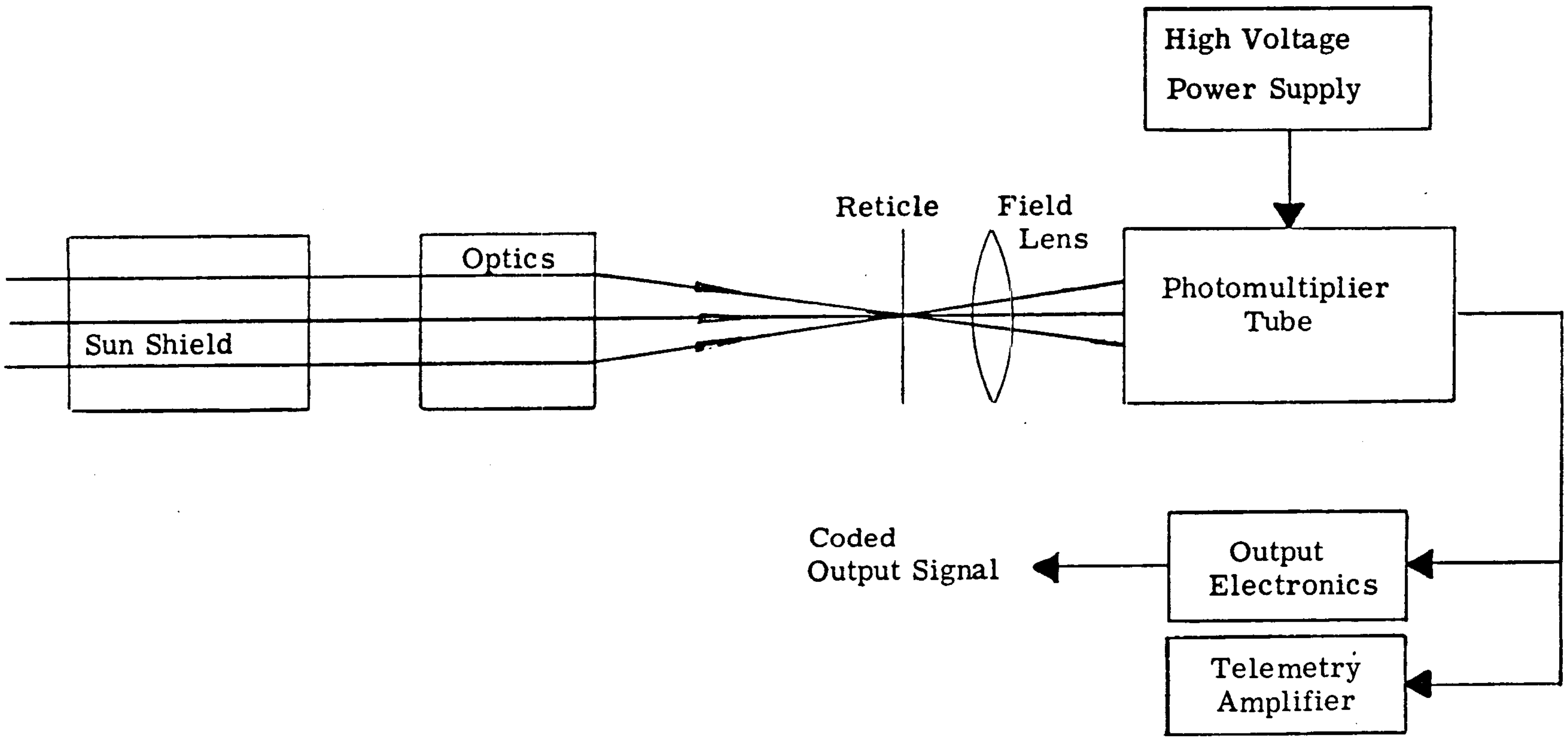


Figure 2.1 PSST SYSTEM BLOCK DIAGRAM

III
OPTICAL DESIGN

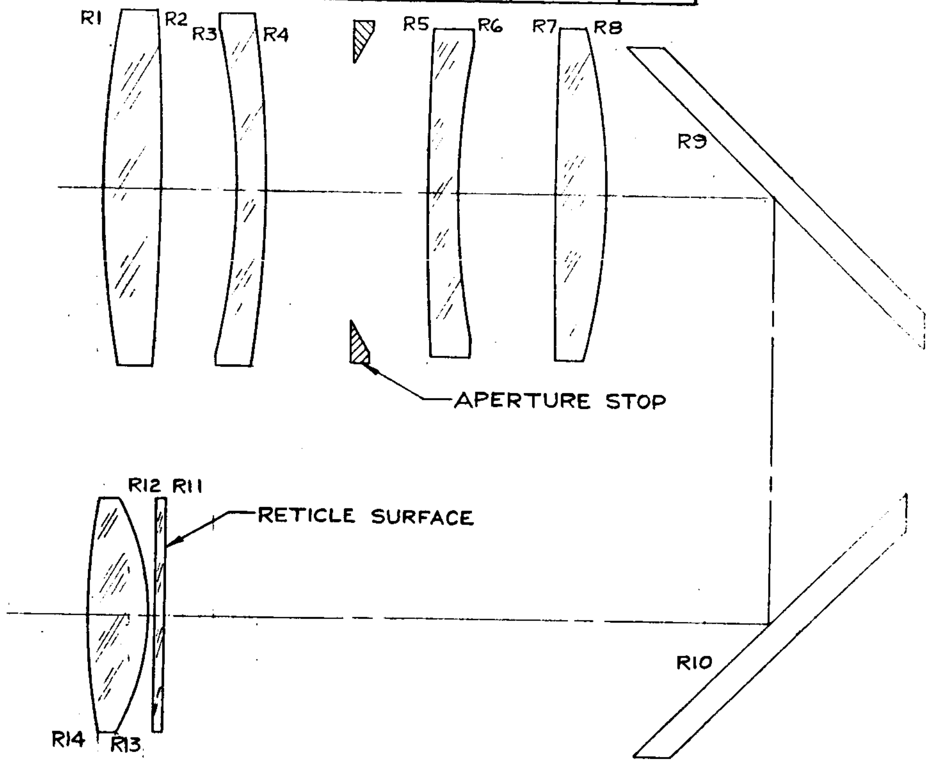
3.1 FINAL SYSTEM DESIGN

The optical system for the Passivenly Scanned Star Telescope has a clear aperture of 2.75 inches and a nominal focal length of 13.75 inches. The aperture is smaller than the specified three inch aperture but is necessitated by the revised optical design. The field of view is 8.424 degrees giving a square 6 x 6 degree reticle field of view. The optical elements in Figure 3.1 were optimized for the wavelength region between 3200A and 6000A and are coated for maximum transmission at 4200A which gives an overall system transmission of 70 to 75%. The glass in the first lens (LBC-2) does not contain materials which are flourescent when subjected to ultraviolet light; therefore, coating the first element to minimize this effect was not judged necessary.

The blur circle, containing 75% of the light from 3400A to 5000A, has a diameter of 0.00252 inch (38 seconds of arc) with an internal pressure in the telescope of 15 psia and vacuum pressure outside. When the internal pressure drops to 8 psia, the blur circle enlarges to 0.00384 inch. With a blur circle radius of 36 seconds of arc, 88% of the energy is contained in the blur circle with a 15 psia internal pressure; and 80%, with 8 psia internal pressure.

A field lens is located approximately 0.050 inch behind the reticle. Depositing the reticle pattern onto the front surface of the field lens was considered, but the lens must be bi-convex to meet the system requirements and the reticle plane should be flat. An alternative solution utilized a compound field lens system with the reticle on the flat surface of the first lens, a plano-convex element. This solution was rejected, because of complexity,

SURF.	RADIUS	THICKNESS GLASS	THICKNESS AIR	CLEAR APERTURE	MATERIAL	TYPE	GRADE	
R1	9.256±0.009	0.545±0.005		2.977	LBC-2	573574	B	
R2	−26.985±0.027		0.718±0.002	2.894				
R3	−6.577±0.007	0.276±0.005		2.640	DF-3	621362	B	
R4	−11.456±0.011		1.568 *	2.613				(SEE NOTE 1)
R5	37.243±0.037	0.278±0.005		2.471	DF-3	621362	B	
R6	7.665±0.008		0.911±0.002	2.470				
R7	41.831±0.042	0.485±0.005		2.646	C-2	513605	B	
R8	−6.173±0.006		1.600 REF.	2.683				(SEE NOTE 4)
R9	∞		4.062 REF.	3.700	ALUMINUM			
R10	∞		5.943 REF.	3.400	ALUMINUM			
R11	∞	0.100±0.005		2.040	BSC-1	511635	B	(SEE NOTE 4)
R12	∞		0.048±0.005					
R13	2.319±0.004	0.556±0.005		2.100	C-2	513605	B	
R14	−5.897±0.006		3.581	2.100				



NOTES:

1. *Adjustable for B. F. L.
2. Centering tolerance ±0. 002.
3. Aperture stop lies 0. 840 in back of R4.
   Aperture stop diameter 2. 4508.
4. Distance between R8 and R11 is 11. 605.

Figure 3. 1 OPTICAL SYSTEM

and cost, in favor of the first approach. The light passing through the reticle will be diffused over 98% of the photocathode surface of the photomultiplier (P/M) tube. An aperture stop in front of the P/M tube has a diameter of 1.00 inch prohibiting the image of the sun shield from impinging on the face of the tube. The vignetting within the square 6 x 6 degree field of view is approximately 5%. The reticle is constructed by depositing a metal film on the first surface of the flat piece of glass in the pattern as specified by NASA Dwg. LG806073. The actual size of the reticle is 2.04 inches square and the δ (0.025 degree) values are 0.0060 inch.

3.2 DESIGN ANALYSIS

3.2.1 Petzval Six Element System

Prior to contract award, first order ray traces were run at the mean wavelength on the submitted system. The system met the specifications at this wavelength and it was assumed, as it turned out wrongly, that the purpose of the doublets was to correct the chromatic aberrations in the system. Figure 3.2 is a conventional representation of the sphero-chromatic aberration and shows that the system performed very well at the mean wavelength but failed badly at 3400A and 5000A. The lens is extremely under-corrected for the 5000A radiation and is extremely over-corrected for the 3400A radiation. In terms of longitudinal intercept, measured along the optical axis, the 4200A light is assumed to represent the nominal mean wavelength. The 3400A light is 0.125909 inch beyond this nominal focal surface, and the 5000A is -0.252113 inch inside the mean focal surface. The mean wavelength of 4200A focusses 0.105687 inch beyond the reticle surface.

Figure 3.3 shows a blur circle diameter of 0.060 inch for the 3400A color as plotted on the mean color plane, for a target on axis. At the edge of the field, the blur circle diameter measures 0.056 inch. Both these values were considered for an energy concentration of 75%. Shifting the plots of the 3400A color to the right of the mean color plane does allow an improvement in these values, as shown in Figure 3.4. However, this artificial improvement still does not produce the required image quality.

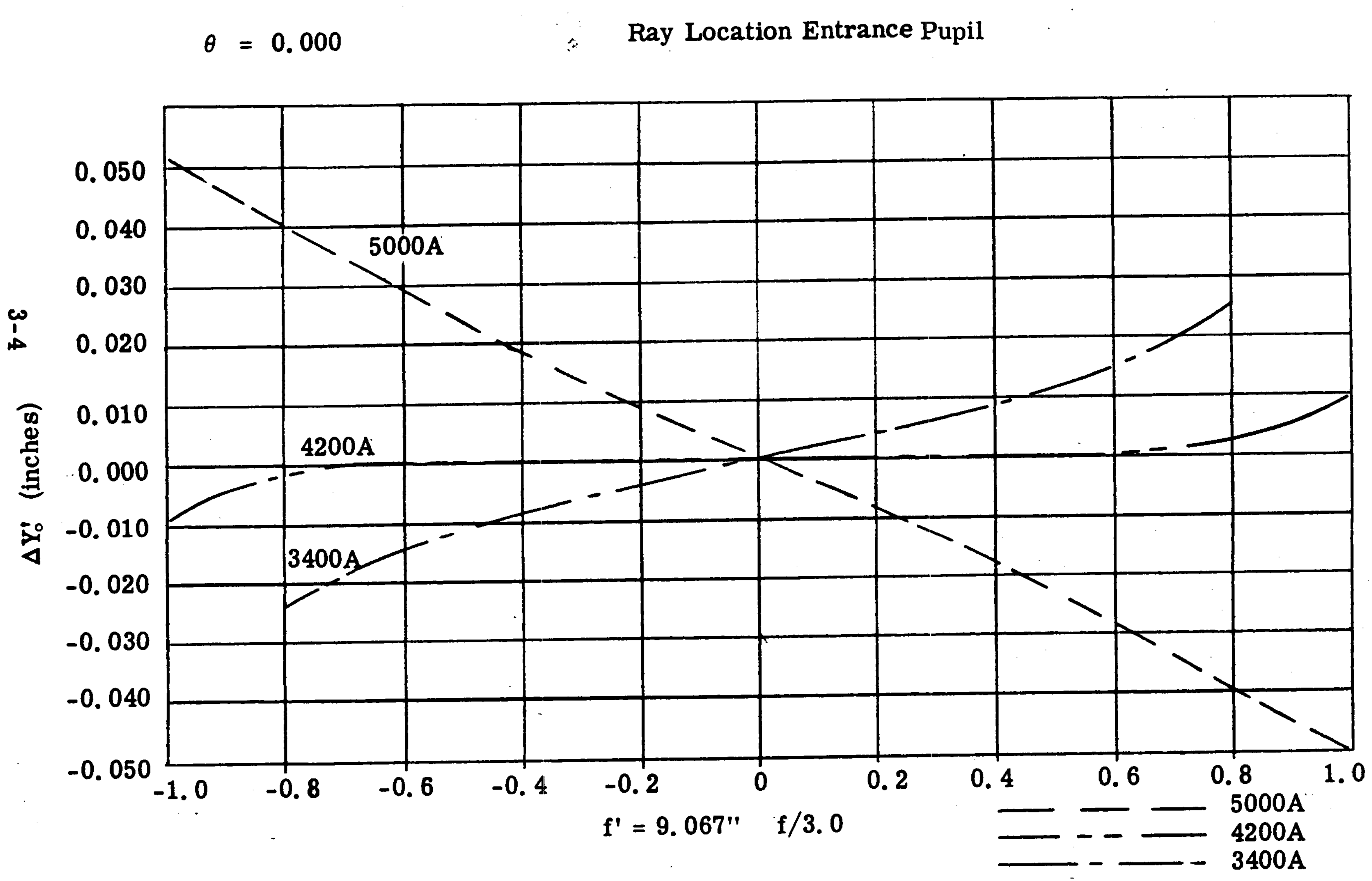


Figure 3.2 SPHERO-CHROMATIC ABERRATION

Spot Diagram for 3400A on 4200A Paraxial Plane

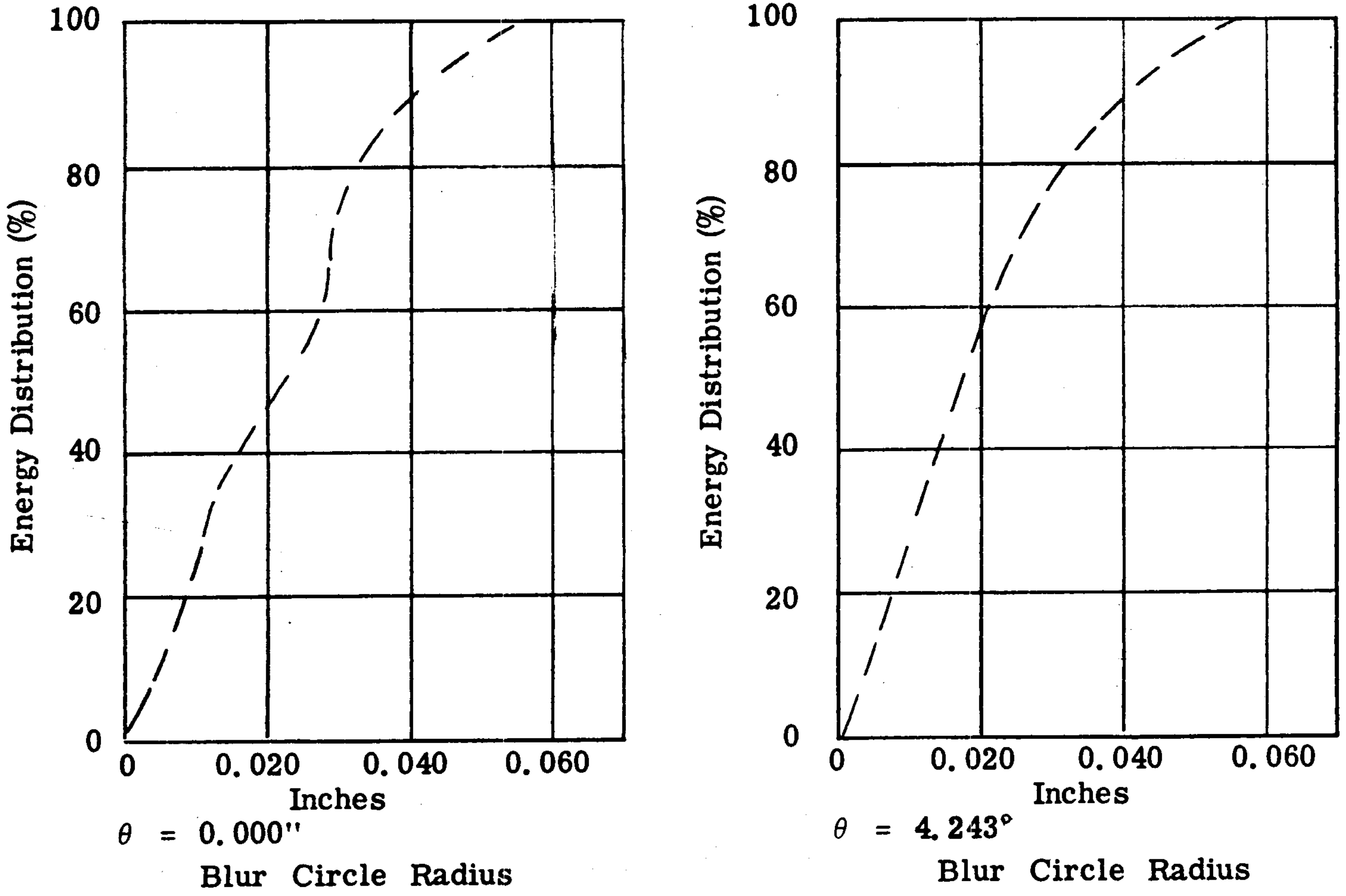
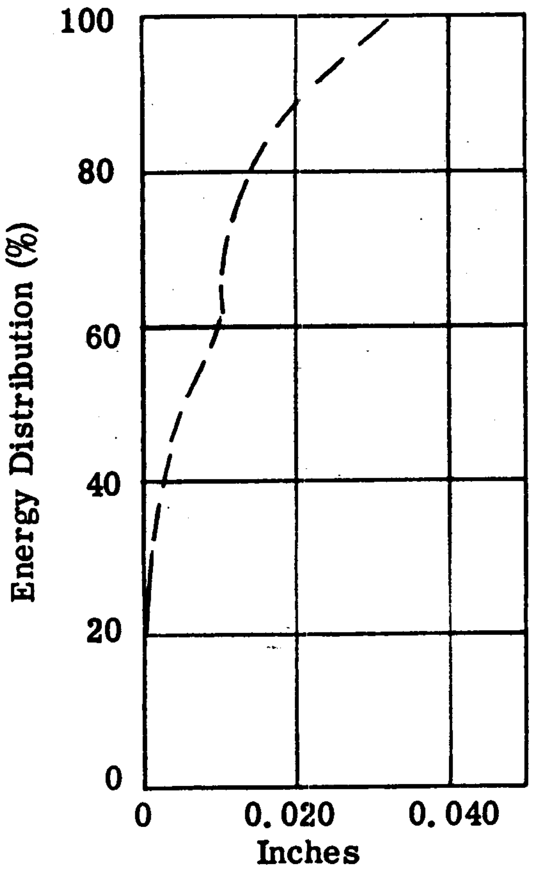
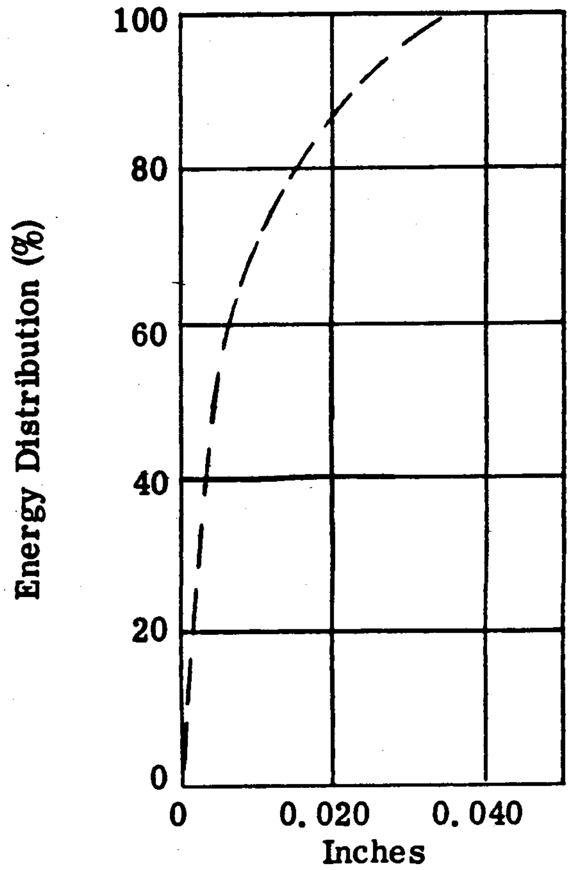


Figure 3.3 BLUR CIRCLE FOR THE 3400A COLOR



θ = 0.000"
Blur Circle Radius



θ = 4.243"
Blur Circle Radius

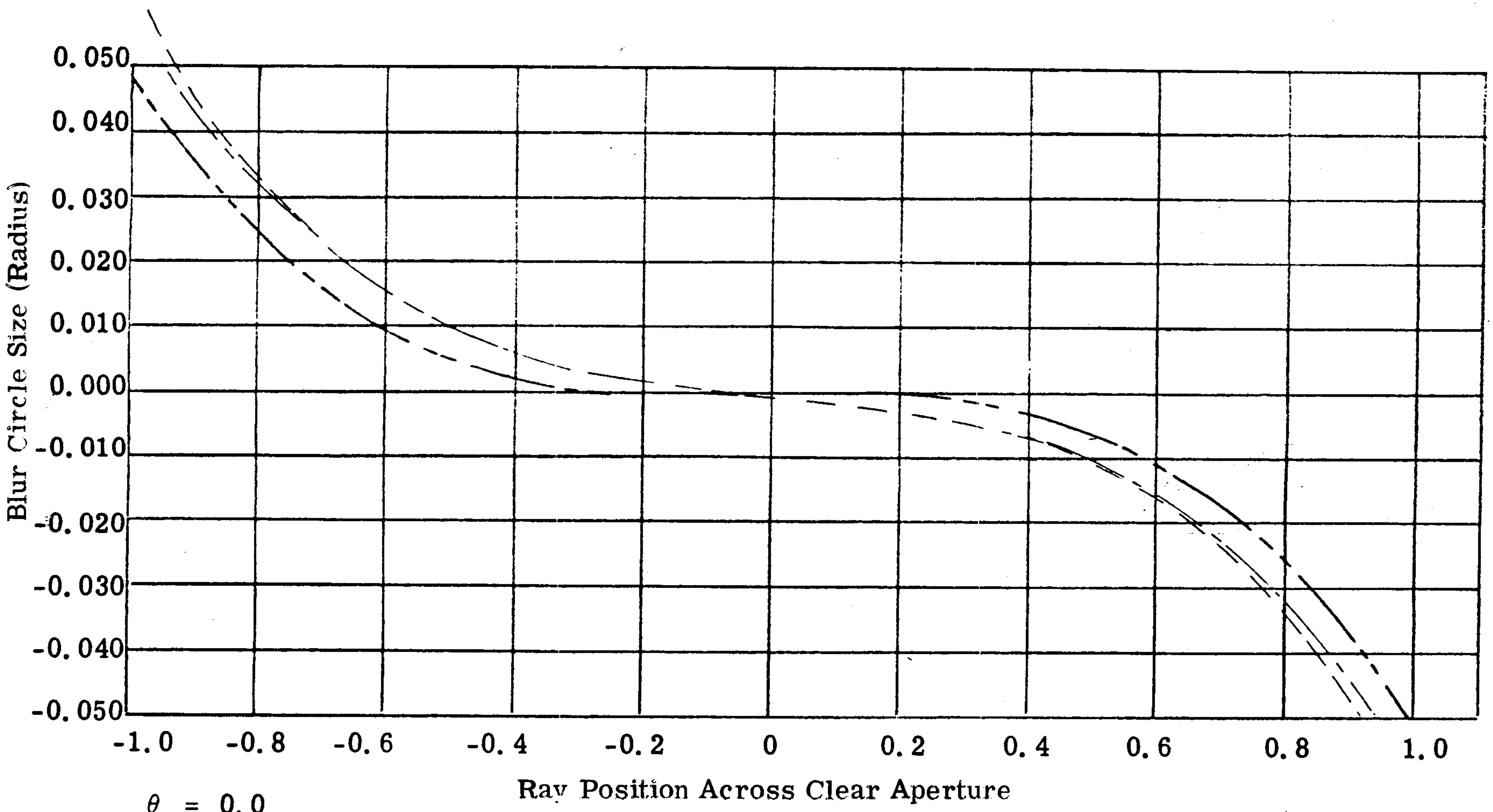
Figure 3.4 BLUR CIRCLE FOR 3400A SHIFTED TO +0.12590929 INCH

These investigations proved that the originally proposed optical system had to be re-designed. Based on the results obtained during the analysis of the proposed system, it was realized that the color was severely unbalanced and there was an excessive amount of longitudinal spherical aberration. While the performance characteristics of the mean color, 4200A, off-axis were adequate, some improvement here would also be helpful to the system performance.

Another serious deficiency of the basic configuration was the extraordinary large amount of secondary spectrum encountered. This is the residual chromatic aberration when a lens system is corrected for the primary wavelengths, in this case 3400, 4200, and 5000A. This effect is present to a degree in all optical systems with this range of wavelengths, but in the proposed system the excessive amount was due primarily to a poor choice of glass types coupled with a physical configuration which produced hyper-chromatic power distribution of the lens elements. The parameters in the optical system which were most critical, were determined to obtain the optimum arrangement of lens surfaces to reduce the total chromatic aberration. By use of a least square correction method, the system was improved as shown in Figure 3.5, but was still short of the specified values.

It appeared that the chromatic conditions could not be fully corrected, so the spherical aberration was reduced to tolerance values to learn how near the proposed optical system was to system specifications.

The final system values are shown plotted in Figure 3.6. The mean wavelength of 4200A is well corrected over the aperture but the ends of the spectrum at 3400A and 5000A still exhibit the unacceptably large color residuals. The blur circle, containing 75% of the energy, is still larger than 0.015 inch, one order of magnitude over the specified value.

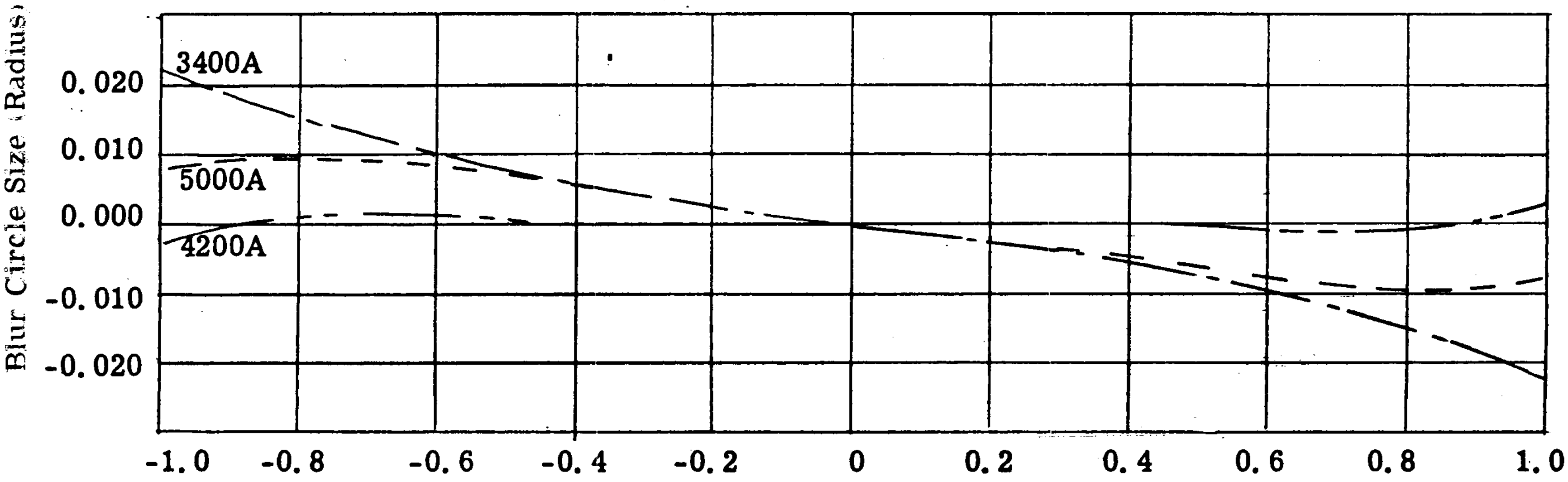


θ = 0. 0

Attempt to balance color only secondary spectrum still dominant

5000A – – – –
3400A —— - ——
4200A —— - - ——

Figure 3. 5 LEAST SQUARE CORRECTION



θ = 0.000
Spherical balanced
Color adjusted (limited by secondary)

Ray Position Across Clear Aperture

Nominal 9" F/3.0

Figure 3.6 FINAL SYSTEM VALUES

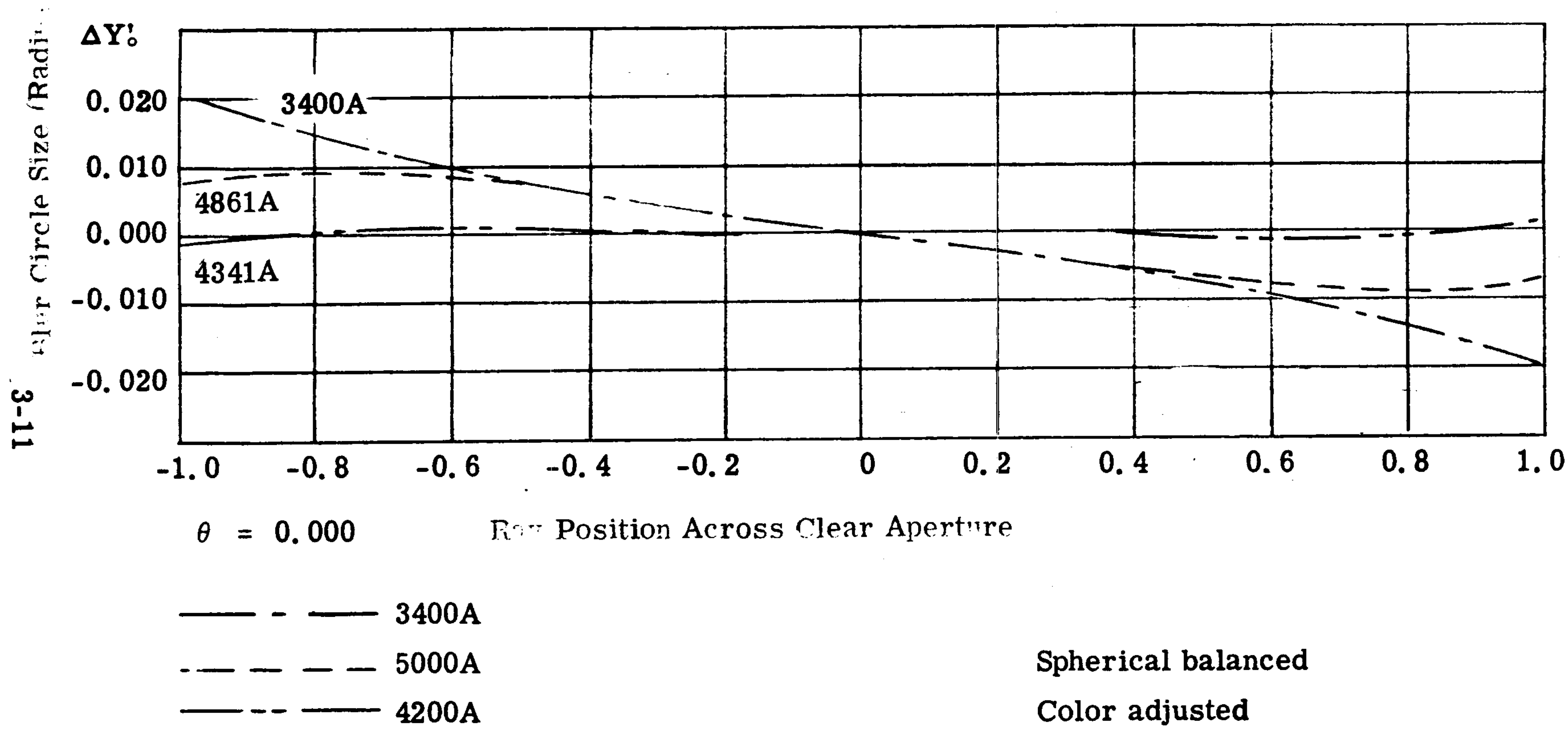
In a further attempt to reduce the color, glass materials for elements No. 3 and No. 4 (the doublet assembly between the folding mirror surfaces) were interchanged and the entire correction procedure was repeated. However, the same general color tendencies still remained as shown in Figure 3.7.

When it became apparent that the suggested f/3 system was not going to be useable, a parallel effort was started on a design composed of a Cooke triplet optimized for 3400 to 5000A.

3.2.2 Modified Cooke Triplet

The basic design developed by Dr. Baker for the Cooke triplet, was modified to an f/5, 2.75 inch clear aperture system. The 2.75 inch aperture area is 16% smaller than that required by the specifications, but this is the maximum possible with this design (3 inch clear aperture of first element) and the size limitations of the vehicle compartment. The ASCOP P/M tubes which are used in the PSST have thermionic noise equivalent power less than 1×10^{-15} watts, and as the tube noise is the largest noise component, the system should still have a signal-to-noise ratio greater than 12 with this change.

The initial attempt at the triplet design showed a considerable amount of sphero-chromatism and some logitudinal spherical aberration caused by over-correction. During subsequent least-square matrix solutions, the amount of sphero-chromatism was reduced, but the spherical over-correction was improved only slightly. This indicated that the variation of high order spherical aberration was very sensitive to small parameter changes and completely non-linear, a characteristic which proved inherent in the design. An analysis of the fifth and seventh order spherical aberrations was run and the results used to try to correct the system. The 3400A and



Spherical balanced

Color adjusted

Figure 3.7 ELEMENTS 3 AND 4 INTERCHANGED

4341A curves showed acceptable behavior but the red end (4861A) still showed a large amount of over-correction. An energy distribution was performed at this point with the results listed in Table III-1.

Table III-1

ENERGY DISTRIBUTION

Percent Energy Level	Radius of Spot (inches)
05	.00009
10	.00009
15	.00091
20	.00091
25	.00091
30	.00095
35	.00095
40	.00095
45	.00163
50	.00180
55	.00180
60	.00181
65	.00182
70	.00586
75	.00587
80	.00589
90	.01274
95	.01285
100	.01304

A 36 arc second radius is 0. 0024 inch at this focal length. Only 66% of the energy is within the blur circle, and, because of the decrease in focal length, at least 80% of the energy must be within the spot to be acceptable. Further attempts to improve this system proved fruitless and this type of system was abandoned.

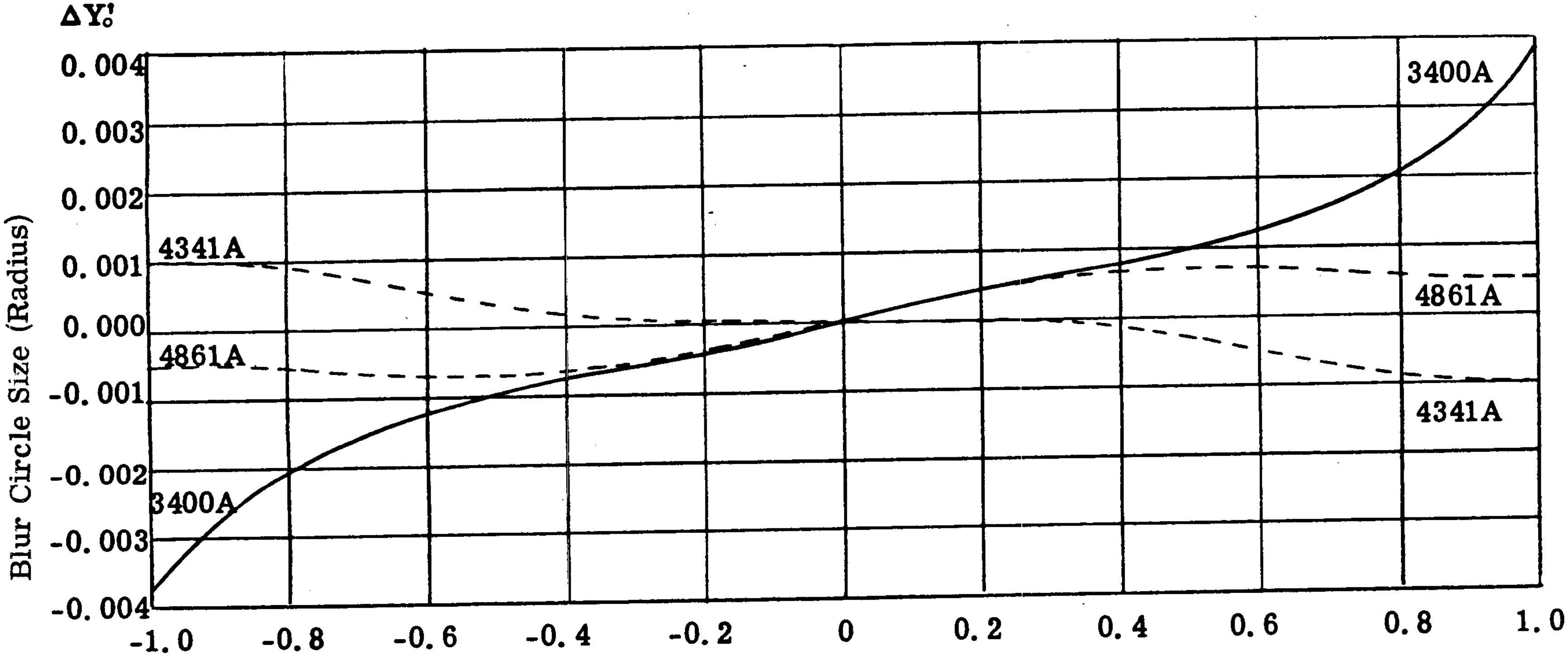
3. 2. 3 Four Element Optical System

A back-up four element system was undergoing progressive improvement at the same time as the triplet system and it showed that it could meet the required specifications. However, the distance between the first vertex of the first lens, and the second vertex of the fourth lens was approximately eight inches. The distance between the second and third lenses was not quite long enough to insert a mirror for folding so it was decided to shorten the system as much as possible. This procedure upset the color balance and caused a strong backward curvature of the field. However after systematic analysis, the design progressed toward its present state as shown in Table III-2 and Figure 3.8.

Table III-2

ENERGY DISTRIBUTION, FOUR ELEMENT SYSTEM

Percent Energy Level	Radius of Spot
05	.00008
10	.00027
15	.00038
20	.00046
25	.00048
30	.00056
35	.00059
40	.00060
45	.00061
50	.00069
55	.00082
60	.00088
65	.00091



θ =. 0.000

13.75" F/5.0 U.V. Lens

Figure 3.8

Table III (Continued)

Percent Energy Leven	Radius of Spot
70	.00094
75	.00126
80	.00158
85	.00195
90	.00264
95	.00373
100	.00451

Approximately 88% of the energy for both on-axis and off-axis lies within a blur circle whose radius is 0.0024 inch (36 arc seconds). The color balance could be improved with additional work but the optical design was terminated at this point because it more than meets the specified requirements. (75% energy in a 36 arc sec radius blur circle.)

The system was then evaluated by computer ray trace methods for a pressure drop to 8 psi. The performance held up very well. At the 75% energy level, a spot radius of 0.00192 inch was obtained. Approximately 85% of the energy falls into a radius of 0.0024 inch. The vignetting of the system is less than 5%.

The optical system in Figure 3.1 has four components as opposed to the original six. The first four optical components are located in front of the first mirror surface simplifying optical alignment, but complicating the sunshield design somewhat. (See Section V for sun shield design.)

The actual optical system has a smaller blur circle than shown above because equal weights were attached to the three colors used in the design study. The spectral response measurements of the flight system (page B-21) show that the effective transmission of 3400A light is only 5% of that at 4200A. Therefore the important contribution is from the 4341A rays. Subsequent measurements show that the measured blur circle diameter is approximately 25 arc seconds.

IV
PHOTOMULTIPLIER SUBASSEMBLY

The photomultiplier (P/M) tube, power supply, output electronics, and telemetry amplifier are supplied as a calibrated subassembly. The output voltage is linearly proportional (within ±6%) over a dynamic range of 20:1. The frequency response is flat within ±0.25 db between 40 cps and 4.5 kc with an 18 db Gaussian roll off above 6 kc, and a 6 db roll off below 25 cps. The P/M subassembly draws 50 milliamps or less when the vehicle power supply voltage is less than 29 volts. The output electronics furnishes a 5 volt output pulse when radiation from an AO-O magnitude star is detected by the optical system.

The multiplier phototube is the specified ASCOP 541 A selected for an anode dark current equal to or less than 2×10^{-9} amps. During evaluation of the frequency response of the tube, a break point was discovered at 3 kc. The frequency response was improved by adding capacitors between the last two dynode stages and ground.

The power supply was purchased from Pulse Engineering Co. with the voltage output specified to give a 10^6 tube gain. The specified voltages for the qualification, flight, and space P/M tubes were 2360, 2370 and 1870 volts respectively. The measured voltages differ by 1 to 3% from these values. This means that the tube gains vary up to 30%. The overall system gains were fixed by the P/M tube load resistor to give the specified calibrated output.

The electronics unit consists of three welded module units which are potted together into a 4.1 x 2.0 x 1.4 inch metal can to reduce the effects of external noise on the amplifier.

Figure 4.1 is the circuit diagram of the output electronics in its final form. The first section of the output electronics consists of a four transistor amplifier with a tuned feedback loop which attenuates the low frequency response below 25 cps at a 6 db per octave slope. The gain varies between 40 and 60 depending on the characteristics of the 2N2609 transistor in the first stage. The last three transistors comprise an active low pass filter (differential amplifier) whose function is to obtain a response slope of 18 db per octave above 6 kc. The gain of this section is one. Several component values (R10 and R16 on Figure 4.1) were quire critical and had to be adjusted with each amplifier in order to keep the flatness within the required ± 0.25 db and still maintain the 18 db rolloff.

Noise at the output of the output electronics units varies from 280 microvolts to 350 microvolts with a low noise 50K load resistor across the input.

The P/M electronics package has two connectors: a C5-R1, made by Glennite Division of Gulton Industries, Inc. for telemetering and an M4P-LS connector, made by Winchester Electronics, for the telescope power input.

Figure 4.2 is a schematic for the telemetry amplifier. This amplifier has a gain of 500 and an input impedance of 200K ohms. The output varies between 0.25 volts and 5 volts for a P/M tube anode current of 0 to 50 microamps (0 to 10 millivolts input to the amplifier). The output of the telemetry amplifier is not proportional to the output current of the P/M tube. This results from the limiting action of CR3 in Figure 4.1 which was inserted in the circuit to keep the amplifier from being over saturated during high P/M anode currents caused by high light level conditions. The diode starts to conduct when the input voltage exceeds 150 millivolts. The telemetry amplifier has a 25 volt volt output for 0 input because the output is d-c connected and no negative supply voltage was available in the spacecraft. The 3 db breakpoints of the amplifier are nominally set at 10 cps and 1.2 kc. The telemetry amplifier is connected to the junction box with a Glennite cable and the amplifier output is a C5-R1, similar to the output electronics. Several problems encountered during testing are described in Section 7.

Figure 4.3 is the interconnection diagram for the PSST P/M subassembly.

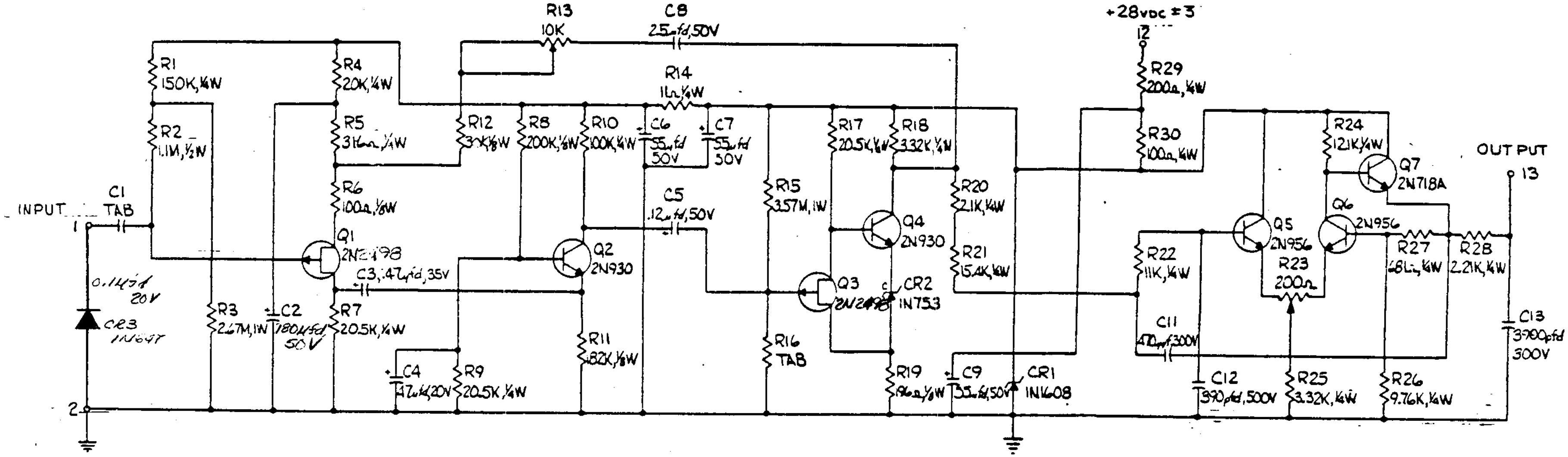


Figure 4.1 SCHEMATIC DIAGRAM, PHOTOMULTIPLIER OUTPUT ELECTRONICS

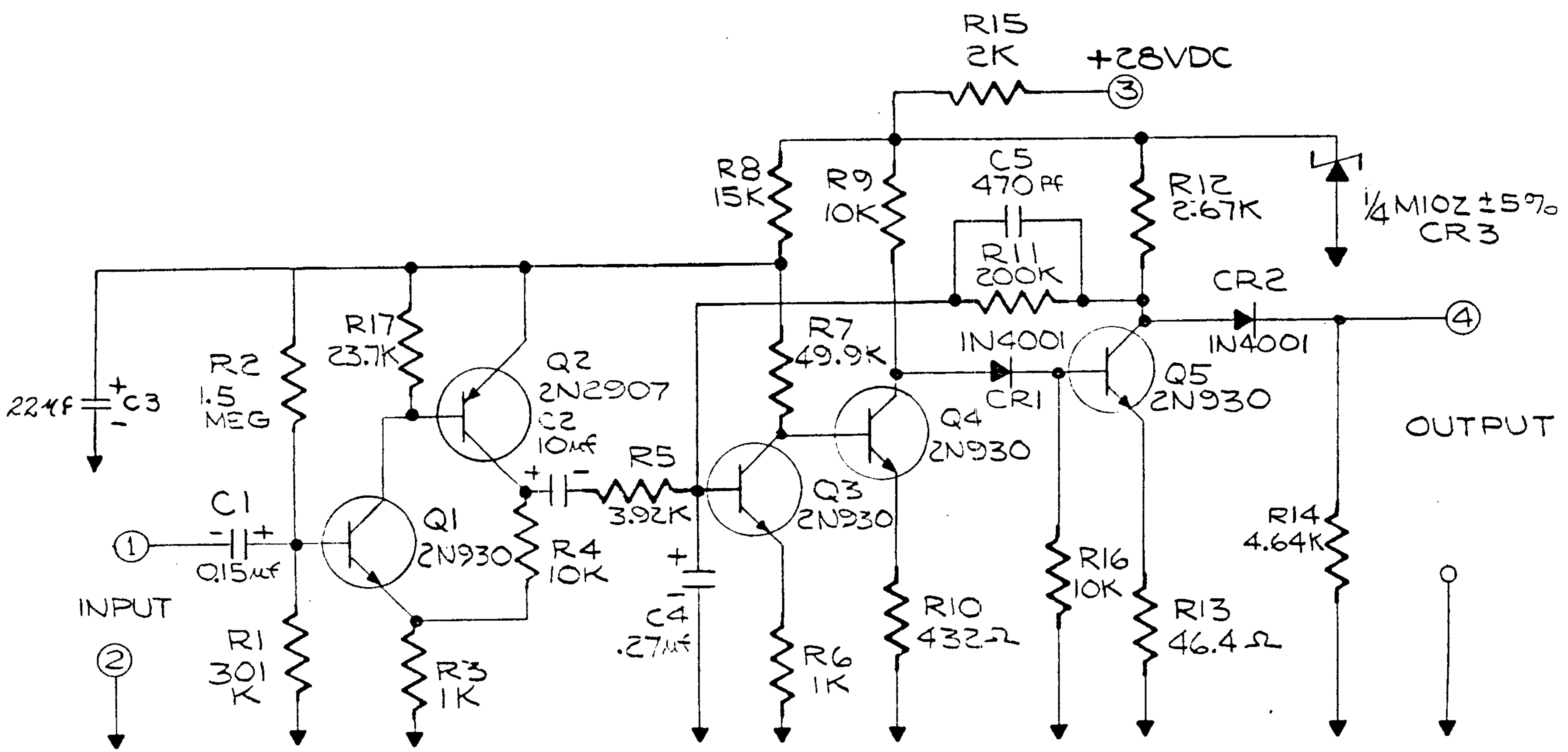


Figure 4.2 SCHEMATIC DIAGRAM, TELEMETRY AMPLIFIER

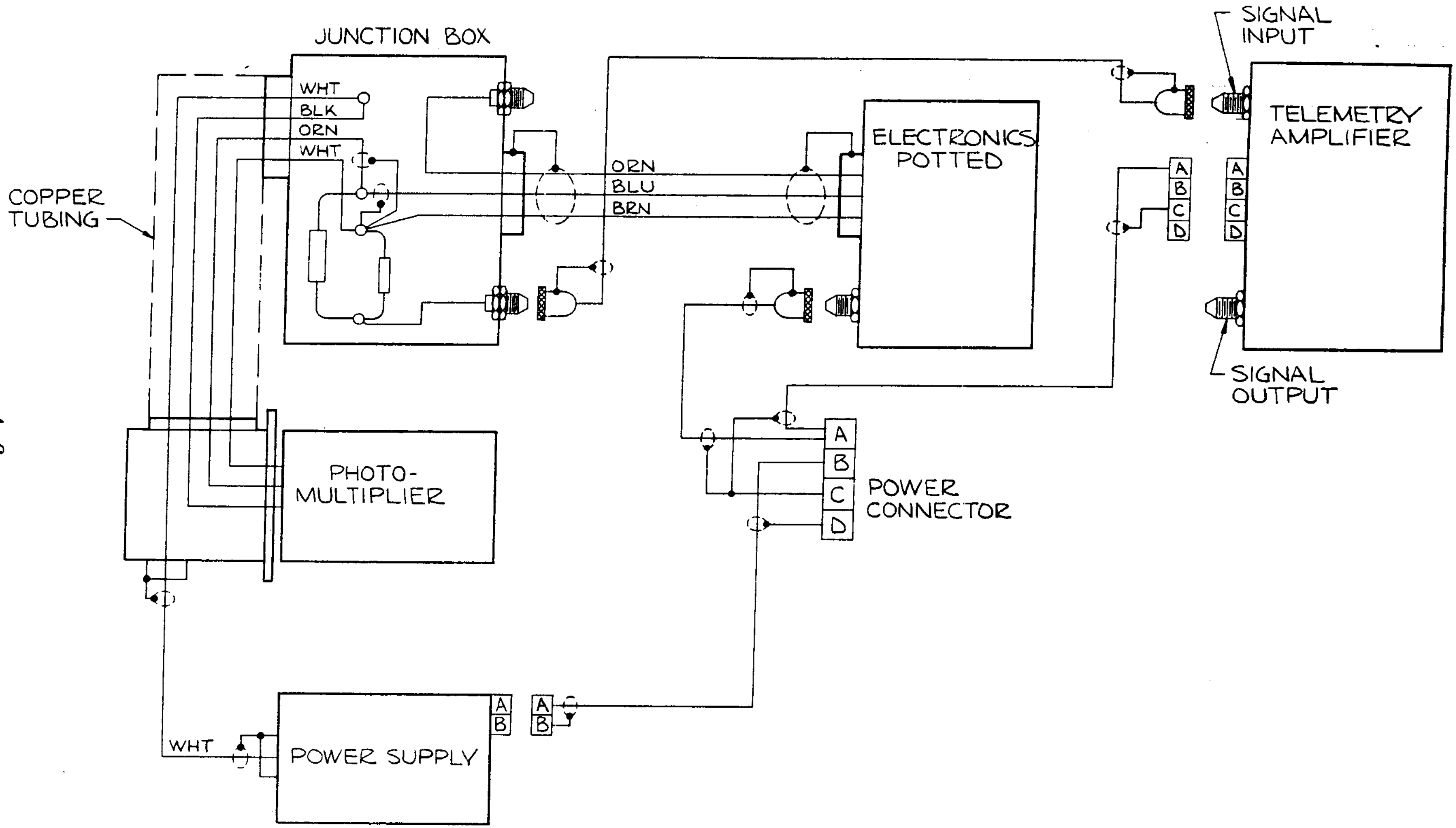


Figure 4.3 P/M SUBASSEMBLY WIRING SCHEMATIC

V
MECHANICAL DESIGN

The Passively Scanned Star Telescope is 5.85 inches high, 16.85 inches long, and 8.5 inches wide. The unit weighs 19.6 pounds. Figure 5.1 shows the overall mechanical design of the telescope which also serves as a pressure seal between the payload interior and the environment of outer space.

The one piece optical base casting is made of Precedent 71 aluminum alloy which, after heat treating, has a dimensional stability on the order of 10^{-6} inches per inch. The stress relieving heat treatment is applied to the raw casting and no subsequent treatment is required.

Subassemblies on this main body are:

1. Sun shield and elastromeric seal - A
2. Lens capsule - B
3. Folding mirror no. 1 - C
4. Folding mirror no. 2 - D
5. Field lens and reticle capsule - E
6. Electronic package - F

5.1 SUN SHIELD

The sun shield is machined from a single piece of Precedent 71 aluminum alloy. The design was discussed at the NASA-Honeywell conference held August 28, 1963. The sun shield prohibits all rays more than 25 degrees off axis from entering the optics. The initial sun shield was polished, tested, painted with 3M Velvet Black pain and cured for 3 hours at 150° F. The test was then repeated. The results of these tests show the blackened sun shield is better and it was selected for the final unit.

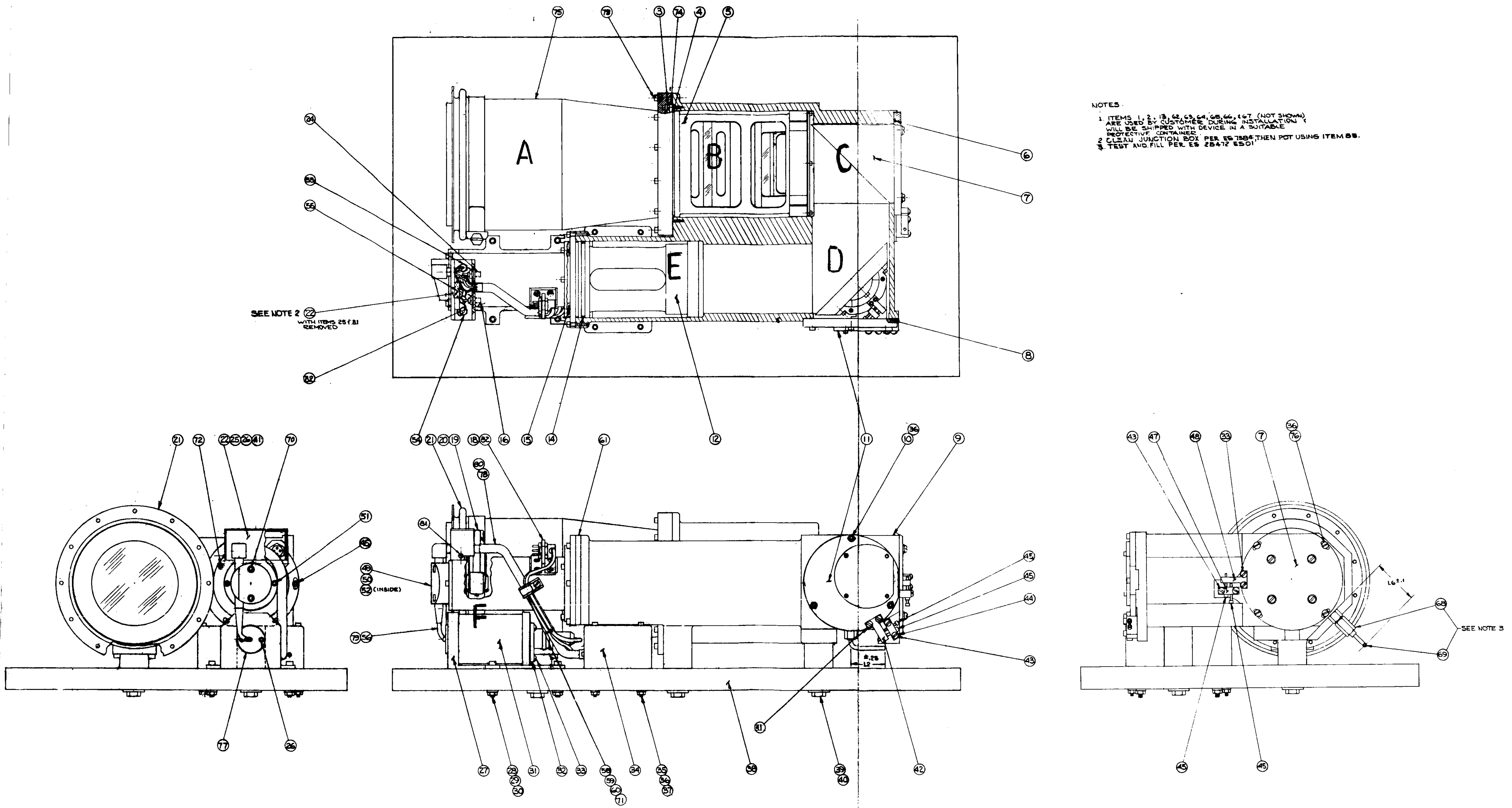


Figure 5.1 MECHANICAL CONFIGURATION

LIST OF MATERIALS

1	1	42755	Ring, Retaining, Boot
2	1	UG1740A1	Jig Plate
3	4		Screw, Hex Soc Hd, Crfs. Nylok, #2-56x3/8 Lg
4	1		"O" Ring, 3.489 1D x .079W, Parker No. 2-43, Viton A
5	1	42820	Ass'y, Main Lens Capsule
6	1		"O" Ring, 2.864 1D x .070W, Parker No. 2-40, Viton A
7	1	42826	Ass'y, Mirror No. 1
8	1		"O" Ring, 2.739 1D x .070W, Parker No. 2-39, Viton A
9	1	42827	Final Machining
10	9		Screw, Hex Soc Hd Cres. Nylok, #4-40 x 1/2 Lg
11	1	42781	Ass'y, Mirror No. 2
12	1	42819	Ass'y Reticle & Field Lens
13	12		Seelscrew, Self Locking, Slotted, #4-40 x 1/2 Type Sl
14	1		"O" Ring, 2487 1D x 103W, Parker No. 2-144, Viton A
15	1		"O" Ring, 1.739 1D x .070W, Parker No. 2-31, Viton A
16	1	42835	Tube Holder
17			
18	1	43942	Connector, Potted
19	1	MS35842-4	Clamp, Hose, Low Pressure
20	AR		Wire, Lock, Cres .03 Dia
21	1	42777	Boot, Seal
22	1	F987936	Box, Junction
23			
24	2		Connector, Receptacle, Glennite No. C5-R1
25	1	F987937	Cover, Junction Box
26	2		Screw, Hex Soc Hd, Cres. Nylok #2-56 x 3/16
27	1	42808	Mount, Power Supply
28	4		Screw, Round Hd Cres, No. 6-32 x 1-1/8 Lg
29	4		Flatwasher, Cres. Pass, #6
30	4		Nut, Hex, Cres. Pass, #6-32
31	1		Power Supply Pulse Engr
32	1	42812	Clamp, Power Supply
33	6		Screw, Round Hd, Cres Nylok, #4-40 x 7/16 Lg
34	1	43935	Electronics, Potted (Amplifier)
35	4		Screw, Round Hd, Cres, #4-40 x 2-1/2 Lg
36	11		Flatwasher, Cres, Pass, #4
37	4		Nut, Hex, Cres. Pass, #4-40
38	1	SK42832	Base, Assembly & Shipping
39	3		Screw, Round Hd, Cres, #1/4-28 x 1-1/8 Lg
40	3		Flatwasher, Cres, Pass, #1/4
41	4		Screw, Round Hd, Cres Nylok, #4-40 x 5/16 Lg
42	1	42780	Cover Lug, Mirror No. 2
43	4		Screw, Mach, Pan Hd, Cres, Nylok #4-40 x 9/16 Lg
44	1	42793	Stop Block Mirror No. 2
45	10		Screw, Hex Soc Hd, Cres. Nylok #4-40 x 3/4 Lg
46			
47	1	42792	Stop Block Mirror No. 1
48	1	42791	Cover Log, Mirror No. 1
49	1	42831	End Cap
50	1		Photomultiplier, Ascop #541A
51	2		Screw, Hex Soc Hd, Cres. Nylok, #4-40 x 1/4 Lg
52	2		"O" Ring, 1.239 I.D. x .070W, Parker No. 2-26, Viton A
53	3		Terminal, Insulated
54	2	MS35431-1	Terminal, Lug
55	2	RN60 Type	Resistor (Select at calibration)
56	AR		Braided Copper Sleeving 1/8 ID When Rounded
57	1		Connector, Plug Glennite
58	1	91411-2	Clamp, Cable
59	1	MS35233-27	Screw, Mach, Pan Hd Slotted, Cres, #6-32 x 5/16 Lg
60	1		Washer, Flat Round, Cres #6
61	1	43937	Spacer
62	3	AN950-4	Washer, Ball Socket

LIST OF MATERIALS (Continued)

63	3	AN955-4	Washer, Ball Seat
64	3	MS35208-6	Screw, Hex Soc Hd, Cres. Pass, 1/4-28 x 3/4 Lg
65	4		Screw, Hex Soc Hd, Cres, Pass #6-32 x 3/8 Nylok
66	4		Screw, Mach Rd Hd, Cres, Pass, #4-40 x 1-3/4 Lg
67	4		Washer, Lock Ext Tooth, #4
68	1		Tube Fitting, Parker #2F5BX-S
69	1		Tubing, Copper, Annealed, 1/8 O.D.
70	2		Screw, Hex Soc Hd, Cres, Pass, #4-40 x 5/16 Lg
71	1		Washer-Cable Clamp D-167
72	3		Screw, Hex Soc Hd Cres, Pass. #6-32 x 3/8 Lg
73	12		Screw, Hex Soc Hd, Cres, Pass #4-40 x 1" Lg
74	1		"O" Ring, 4.239 I.D. x .070W, Parker N-2-46 Buna N
75	1	42757	Sun Shield and Extension
76	4		Screw, Pan Hd, Cres Nylok #4-40 x 9/16 Lg
77	1	43943	Retainer, Shield
78	AR		Braided Copper Sleeving, 1/4 I.D. when Rounded
79	AR	M.H.M.S. 7247 #12	Tubing, Natural Irradiated Polyolefin, Heat Shrinkable
80	AR	M.H.M.S. 7247 #8	Tubing, Natural, Irradiated Polyolefin, Heat, Shrinkable
81	2	MS35233-2	Screw, Mach Pan Hd Cres 2-56 x 3/16 Lg
82	5	MS35233-12	Screw, Mach Pan Hd, Cres 4-40 x 3/16 Lg
83	AR	MS7384	Potting Compound Sylgard 184

Ray traces of the sun shield show that it reflects all light rays greater than 25 degrees off center line out of the system. The sun shield is an integral part of both the qualification unit and the final unit as it includes one main support leg. This was done to avoid the use of a "shock absorber" fourth leg supporting the sun shield. The sun shield is sealed to the main body of the instrument by a standard O-ring.

The bellows is a rubber boot which acts as an expansion joint and pressure seal between the vehicle mounting ring and the sun shield. It will withstand a pressure differential of 15 psia and allow a 1/8 inch expansion of the payload heat shield away from the telescope. The boots were made out of two materials: fluorinated rubber (Viton "A" or equivalent), and silicone rubber (50 durometer). The boot made from silicone rubber was supplied with the tracker because it was easier to seal without cutting into the rubber. A spare boot made of Viton A is available.

5.2 OPTICAL SYSTEM

The lenses are mounted in their seats with mylar padding, and elastomeric seal, a frictional washer, and a retaining nut. The seat of the lens is an integral part of the optical tube. This seat was machined flat for plano-mounting surfaces and tapered for curved mounting surfaces. The mylar padding, 0.001 inch to 0.002 inch thick, is used on one side of the lens to minimize the effect of the different finishes between the seat and the glass. This padding distributes the stresses which are caused by a line contact between the glass and metal over the entire seat-to-glass area. During environmental testing it was found that the lenses had to be bonded to the spaces with a flexible adhesive (EC 801) to keep the spacers in place. This is discussed in more detail in Section 7.1.

The lens is held in position by the elastomeric seal on the other side of the lens. This condition of symmetrical stress is represented by concentric isobars with decreasing value toward the center of the lens in such a way that the equivalent strain does not affect the optical path. The elastomeric seal has four functions:

1. To produce a surface contact on that side of the lens
2. To abort the thermal stresses by accommodating the thermal expansion through higher deformation of the representative spring
3. To reduce the effects of shock
4. To act as a seal

A frictional washer between the elastomeric seal and a retaining nut prevents destruction of the elastomeric seal while it is being compressed to the proper installation dimensions or preload.

The retaining stresses imposed by compression of the elastomeric seal is greater than the stress imposed by vibration, shock, or thermal expansion caused by the 70° to 100° temperature differential. The 50G shock and -40G vibration environments are both exerted along the X axis which is penpendicular to the optical center line. These forces are along the radial dimensions of the lenses. The vibration forces along the Y axis, the axis parallel to the optical axis, and the forces caused by angular acceleration will tend to deform the lenses. The largest vibration in this axis is 10G.

The center of the fourth lens is approximately 4.5 inches from the vehicle spin axis and will be subjected to a 70G acceleration. Calculations show that this lens deforms less than 10^{-4} inch, which is less than 0.1% of its thickness (0.485 inch). Two to three percent[1] deformation is generally considered the area where the elastic properties of glass no longer follow Hooke's Law.

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1. State of the Art Report, Optical Materials for Infrared Instrumentation, University of Michigan, Willow Run Laboratories, Report No. 2389-11-S January 1959, page 9.

A third lens is thinner (0.278 inch) but is closer to the spin axis and deforms approximately the same amount. The results of reasonant frequency calculations for the lenses show that the value is above 6 kc for all lenses. The maximum specified vibration test is 2 kc.

The reticle is structually the weakest element because of its thickness (0.1 inch); however, shock, X and Z axis vibration, and spin acceleration are all imposed in a radial direction. (The reticle is less than an inch from the spin axis.) Calculations show that the axial deformation of the reticle caused by 10G of vibration is 0.0005 inch or 0.5% of its thickness, well within the referenced safety factor. A holding fixture for a dummy reticle was fabricated and reticles tested at 60G from 100 to 2000 cps. No breakage occurred.

The inside of the optical housing is scored and blackened to reduce the effects of stray light being reflected from the walls of the optical housing.

An optical capsule consisting of two tubes, one inside the other, supports the four lenses. Two lenses separated by spacers are mounted in the inner tube which, in turn, is mounted in the larger tube along with the aperture stop and the other two lenses. These lenses are also separated by spacers. The whole optical assembly is sealed in place by standard O-rings and retaining nuts.

Folding mirror assembly No. 1 consists of an aluminum mirror mounted to allow one degree of freedom, i.e. rotation. The rotational movement is obtained by antagonistic acting screws that position as well as serve as locking mechanism.

The folding mirror assembly No. 2 has two degrees of rotational freedom. The adjusting mechanisms for this assembly are similar to that used for mirror assembly No. 1. Adjustment of the two mirrors aligns the optical axis of the lens all to the center of the reticle.

The field lens and reticle assembly is mounted in a removable capsule by an O-ring and retaining nut. This capsule was made adjustable for fine focusing. The photomultiplier tube (P/M) is sealed with an O-ring and held in place by a clamp. This clamp holds the P/M tube in place and protects the tube during the installation of the heat shield.

5.4 PHOTOMULTIPLIER SUBASSEMBLY

The P/M subassembly consists of three separate units; the P/M tube holder, power supply and mount, and output electronics. The latter two are mounted to the base plate. All three are removed as a unit in case of failure of any component. This method was approved by NASA as required by paragraph 3.2.4 of specification L-3300.

VI
RELIABILITY PREDICTION

This section summarizes the reliability prediction based on an analysis of the major components which may contribute to failure. Table VI-1 is a breakdown of the electronic components with their stresses and the corresponding failure rates, as extracted from MIL-HDBK-217. Table VI-2 is the failure rate prediction for the Pulse high voltage power supply. Data for this table was supplied by Pulse Engineering Corporation.

Contributing components:

1. Photomultiplier
2. Amplifier-filter
3. High voltage power supply
4. Dynode bias resistors

Equation:

$$R = e^{-K t}$$

K = operating mode factor for missile equipment in flight $K = 10^{3}$*

t = mission time: $t = 0.25$ hour

<u>Total of component failure rates</u>

Photomultiplier	0.500% per 1000 hr
Amplifier filter	1.500% per 1000 hr
High voltage power supply	0.664% per 1000 hr
Dynode bias resistors	0.290% per 1000 hr
	2.954% per 1000 hr

*A factor of 10^3, applied to the failure rate has frequently been used to account for effects of launch environment, particularly vibration.

TABLE VI-2

RELIABILITY FAILURE RATE PREDICTION

HIGH VOLTAGE POWER SUPPLY

Part	Part No.	Mfg.	No.	Failure Rate %/1000 hrs.	Sub. Total
Capacitor	RH16C x 103 M	San Fernanado	24	0.001	0.024
Capacitor	306AD30	Sprague	1	0.002	0.002
Capacitor	109D	Sprague	1	0.013	0.013
Choke	MLA-5	Pulse	1	0.062	0.062
Diode	FD-285	Fairchild	24	0.013	0.312
Diode	SV-11	Transitron	1	0.017	0.017
Resistor	RC20	Allen-Bradley	4	0.001	0.004
Resistor	RC07	Allen-Bradley	24	0.001	0.024
Transformer	PE3994	Pulse	1	0.070	0.070
Transistor	2N498	Texas Instrum.	2	0.034	0.068
Transistor	2N656	Texas Instrum.	2	0.034	0.068

Calculated F. R. 0.664 %/1000 hrs.   Allocated F. R. 0.930%/1000 hrs.

TABLE VI-1

RELIABILITY FAILURE RATE PREDICTION
AMPLIFIER FILTER

RELIABILITY PREDICTION

CIRCUIT SYMBOL	PART NUMBER	RATED VALUE	MAY USE VALUE	STRESS RATIO	FAILURE RATE %/1000 HRS.
		(Volts)	(Volts)		
C1	150D103X9020A2	20	10.0	0.5	.050
C2	109D187X0025T2	25	18.0	0.72	.200
C3	150D474X9035A2	35	1.8	<0.1	.008
C4	150D476X9020R2	20	2.0	0.1	.008
C5	150D124X9050A2	50	12.8	0.26	.015
C6	109D556C2050T2	50	21.0	0.42	.028
C7	109D556C2050T2	50	21.0	0.42	.028
C8	113D255C7050D1	50	5.7	0.11	.008
C9	109D556C2050T2	50	28.0	0.56	.071
C11	TY06-471F	300	0.2	<0.1	.002
C12	CYFM15C391G	300	11.4	<0.1	.002
C13	TY09-392J	300	11.5	<0.1	.002
		(Watts)	(MW)		
Q1	2N2498	1.5	2.4	<0.1	.020
Q2	2N930	0.3	0.2	<0.1	.020
Q3	2N2498	1.5	5.4	<0.1	.020
Q4	2N930	0.3	13.3	<0.1	.020
Q5	2N956	0.5	15.3	<0.1	.020
Q6	2N956	0.5	3.0	<0.1	.020
Q7	2N718A	0.5	12.8	<0.1	.020
CR1	1N1608	10.0	276.0	<0.1	.010
CR2	1N753A	0.4	14.7	<0.1	.010
R1	RN65C1503F	0.25	.008	<0.1	.031
R2	RN70C1104F	0.50	*	<0.1	.026
R3	RN75C2674F	1.0	.150	<0.1	.023
R4	RN65C2002F	0.25	.51	<0.1	.031
R5	RN65C3160F	0.25	8.0	<0.1	.031
R6	RN60C1000F	0.125	.004	<0.1	.039
R7	RN65C2052F	0.25	5.2	<0.1	.031
R8	RN60C2003F	0.125	1.8	<0.1	.039
R9	RN65C2052F	0.25	.166	<0.1	.031
R10	RN65C1003F	0.25	*	<0.1	.031
R11	RN60C1823F	0.125	.012	<0.1	.039
R12	RN60C3012F	0.125	*	<0.1	.039
R13	3280P-1-103	1.0	*	<0.1	.023
R14	RN65D11R0F	0.25	*	<0.1	.031
R15	RN75C3574F	1.0	.005	<0.1	.023
R16	RN70B(2464-2014)F	0.5	.028	<0.1	.026
R17	RN65C2052F	0.25	9.230	<0.1	.031
R18	RN65C3321F	0.25	23.846	<0.1	.031
R19	RN60C1960F	0.125	2.0	<0.1	.039
R20	RN65C2101F	0.25	.016	<0.1	.031
R21	RN65C1542F	0.25	1.041	<0.1	.031
R22	RN65C1102F	0.25	.014	<0.1	.031
R23	3280P-1-201	1.0	1.8	<0.1	.023
R24	RN65C1212F	0.25	5.963	<0.1	.031
R25	RN65C3321F	0.25	29.88	<0.12	.031
R26	RN65C9761F	0.25	12.864	<0.1	.031
R27	RN65C6810F	0.25	.940	<0.1	.031
R28	RN65C2211F	0.25	.114	<0.1	.031
R29	RN65D2000F	0.50	105.8	<0.21	.026
R30	RN65D1000F	0.50	52.9	<0.1	.026
				TOTAL	1.500

* Negligible

Prediction:

$$R = e^{-Kt} = e^{-(2.954 \times 10^{5} \times 10^{3} \times 0.25)} = e^{-0.00734}$$

$$R = 0.9926$$

The reliability prediction for the PSST TM amplifier and earth shine protection amplifier is given in Table VI-3. All failure rates used in this prediction have been taken from MIL-HDBK-217, Reliability Stress and Failure Rate Data for Electronic Equipment, 8 August 1962.

TABLE VI-3

PSST

TM AMPLIFIER

Reference Designation	Part	Manufacturer and Type		Value	Rating	Use	Stress Ratio	Failure Rate %/1000 Hrs.
R1	Resistor, Carbon Film		RN60C	301 K ohms	0.125 watt	0.001 watt	<0.01	0.027
R2	Resistor, Carbon Film		RN70C	1.5 M ohms	0.500 watt	0.001 watt	<0.10	0.034
R3	Resistor, Carbon Film		RN60C	1.0 K ohms	0.125 watt	0.001 watt	<0.10	0.022
R4	Resistor, Carbon Film		RN60C	10 K ohms	0.125 watt	0.001 watt	<0.10	0.022
R5	Resistor, Carbon Film		RN60C	3.92 K ohms	0.125 watt	0.001 watt	<0.10	0.022
R6	Resistor, Carbon Film		RN60C	1.0 K ohms	0.125 watt	0.001 watt	<0.10	0.022
R7	Resistor, Carbon Film		RN60C	49.9 K ohms	0.125 watt	0.001 watt	<0.10	0.022
R8	Resistor, Carbon Film		RN60C	15 K ohms	0.125 watt	0.002 watt	<0.10	0.022
R9	Resistor, Carbon Film		RN60C	10 K ohms	0.125 watt	0.010 watt	<0.10	0.022
R10	Resistor, Carbon Film		RN60C	432 ohms	0.125 watt	0.001 watt	<0.10	0.022
R11	Resistor, Carbon Film		RN60C	200 ohms	0.125 watt	0.001 watt	<0.10	0.027
R12	Resistor, Carbon Film		RN60C	2.67 K ohms	0.125 watt	0.032 watt	0.26	0.026
R13	Resistor, Carbon Film		RN60C	46.4 ohms	0.125 watt	0.002 watt	<0.10	0.022
R14	Resistor, Carbon Film		RN60C	4.64 ohms	0.125 watt	0.009 watt	<0.10	0.022
R15	Resistor, Carbon Film		RN70C	2 K ohms	0.500 watt	0.220 watt	0.44	0.018
R16	Resistor, Carbon Film		RN60C	10K ohms	0.125 watt	0.001 watt	<0.10	0.022
R17	Resistor, Carbon Film		RN60C	23.7 K ohms	0.125 watt	0.001 watt	<0.10	0.022
CR1	Diode, Silicon	Motorola	1N4001	$T_n = 0$	PIV = 50 volts	neg	<0.10	0.010
CR2	Diode, Silicon	Motorola	1N4001	$T_n = 0$	PIV = 50 volts	neg	<0.10	0.010
CR3	Diode, Silicon	Motorola	1/4M10Z	$T_n = 0$	0.250 watt	0.055 watt	0.22	0.013
Q1	Transistor, Silicon	Fairchild	2N930	$T_n = 0$	0.600 watt	0.15 watt	0.25	0.030
Q2	Transistor, Silicon	Motorola	2N2907	$T_n = 0$	0.600 watt	0.120 watt	0.20	0.026
Q3	Transistor, Silicon	Fairchild	2N930	$T_n = 0$	0.600 watt	0.15 watt	0.25	0.030
Q4	Transistor, Silicon	Fairchild	2N930	$T_n = 0$	0.600 watt	0.15 watt	0.25	0.030
Q5	Transistor, Silicon	Fairchild	2N930	$T_n = 0$	0.600 watt	0.15 watt	0.25	0.030
C1	Capacitor, Solid Tant.	Sprague	150D Series	0.15μf	35 volts	3.5 volts	0.10	0.004
C2	Capacitor, Solid Tant.	Sprague	150D Series	10μf	20 volts	5.0 volts	0.25	0.006
C3	Capacitor, Solid Tant.	Sprague	150D Series	22μf	15 volts	4.5 volts	0.30	0.008
C4	Capacitor, Solid Tant.	Sprague	150D Series	0.27μf	35 volts	3.5 volts	0.10	0.004
C5	Capacitor, Dipped Mica	Sangamo	D1S Series	470$\mu\mu$f	500 volts	neg	<0.10	0.001

$\Sigma\lambda = 0.598 \times 10^{-5}$,

MTBF = 167,000

TABLE VI-3 (Continued)

PSST

EARTH SHINE PROTECTION AMPLIFIER

Reference Designation	Part	Manufacturer and Type		Value	Rating	Use	Stress Ratio	Failure Rate %/1000 Hrs.
R1	Resistor, Carbon Film			3.9 K ohms	0.500 watt	0.172 watt	0.34	0.017
R2	Resistor, Carbon Film			100 K ohms	0.500 watt	neg.	<0.10	0.015
R3	Resistor, Carbon Film			4.7 K ohms	0.500 watt	0.004 watt	<0.10	0.015
R4	Resistor, Carbon Film			100 ohms	1.000 watt	0.810 watt	0.81	0.022
R5	Resistor, Carbon Film			6.2 K ohms	0.500 watt	0.048 watt	0.10	0.015
R6	Resistor, Carbon Film			91 K ohms	0.250 watt	neg	<0.10	0.015
R7	Resistor, Carbon Film			560 ohms	0.500 watt	0.026 watt	<0.10	0.015
R8	Resistor, Carbon Film			300 ohms	0.500 watt	0.003 watt	<0.10	0.015
R9	Resistor, Carbon Film			43 K ohms	0.500 watt	neg.	<0.10	0.015
R10	Resistor, Carbon Film			6.2 K ohms	0.500 watt	0.060 watt	0.12	0.015
C1	Capacitor, Glass			331 $\mu\mu f$	100 volts	19 volts	0.19	0.001
CR1	Diode		1N751		0.400 watt	neg	<0.10	0.010
CR2	Diode		1N608			neg	<0.10	0.010
Q1	Transistor		2N1711		0.800 watt	neg	<0.10	0.020
Q2	Transistor		2N2905		3.000 watt	neg	<0.10	0.020
Q3	Transistor		2N1711		0.800 watt	neg	<0.10	0.020
Q4	Transistor		2N1711		0.800 watt	neg	<0.10	0.020
Q5	Transistor		2N1711		0.800 watt	neg	<0.10	0.020
	Cell, Silicon (3)	Clairex,	CL905HLL					0.045*
	Relay	Comp. Co.	HVLEL1A245M					30.015
							$\Sigma\lambda$ =	30.340 MTBF
								= 3200 Hrs.

* Failure rate of a carbon film resistor assumed to be equivalent to that of a cell.

VII
EVALUATION AND CALIBRATION

During the evaluation and testing of the PSST, several problem areas were uncovered. The evaluation of these and their solutions are discussed below. Appendices A, B, and C describe the Acceptance Test Procedures, the Flight Unit Quality Test data, and the Spare Unit Quality Test data.

7.1 FREQUENCY RESPONSE OF P/M TUBE

During the acceptance testing of the P/M subassembly, a discrepancy was noted between the subassembly output and the amplifier output. Since the frequency response of the P/M tubes normally extends into the megacycle range, it was felt that the error was in the testing procedure and changes in the test set up were made. When this failed to improve the response time of both the subassembly and the tube was measured, and the response of the specified 541A P/M tube was compared to the known response of an RCA 7102. The conclusions were that the 541A has a definite roll off starting at approximately 1 kc with the break point at 3 kc.

The time constants of most P/M tubes are governed by the output resistance and capacitance and not by the internal structure of the tube or the bleeder string. A proposed solution of adding capacitors to the last two dynode stages was tried on the unpotted tube at NASA-Langley. The addition of these capacitors moved the break point out to 30 kc and all three ASCOP tubes were returned to the vendor for modification.

7.2 MISALIGNMENT ERRORS

Alignment errors (2 to 3 arc minutes) were noted after the 60G vibration sustained along the X axis. Upon disassembly of the main lens cell, the retaining rings were found to have loosened and two of the lenses had to be rotated. The lens cell was re-assembled and the retaining rings secured with Loctite "A". Greasepaint marks were put on the lenses and the unit vibrated in the X axis. The lenses again rotated. Upon disassembly, the retaining rings were found to be tight. Adhesives were used to fasten the lenses to the spacers, and set screws and adhesives were used to secure the main lens cell. During the third vibration, alignment errors were within the required limits. These changes were incorporated into the flight unit and the alignment error was within tolerance after all environmental tests.

7.3 AMPLIFIER OSCILLATIONS

It was noticed that the first amplifier oscillated at approximately 40 kc after it was potted. The oscillations occur only with a high impedance (30-50K) input and were not detected before potting. We shielded the input lead to isolate it from the feedback loop and detected no oscillation in any of the other units before potting. However, they still oscillated after potting. The oscillations could be stopped by putting approximately 50 $\mu\mu$f in parallel with the load resistor.

The reason was not completely dertermined but it appeared that potting compound used had magnetic properties which couple the feedback into the input. The packaging design was changed and a glass foam potting compound was substituted. This eliminated the oscillations.

An additional ringing with a time constant of approximately 1 second was not discovered until after delivery. Again the breadboard unit did not exhibit this characteristic and the exact cause is unknown. The slope of the roll off below 25 cps was altered to eliminate a tendency for the slope to approach zero near 1 cps and no further problems were encountered.

7.4 OUTSIDE CALIBRATION

The Honeywell star simulator was the initially proposed calibration instrument. However, due to technical difficulties with this instrument, an approach was selected using actual measurements from selected stars.

The object of this test was to determine the value of P/M tube load resistor required to give 5.0 volts at the amplifier output when the telescope is exposed to the radiation from a 0-magnitude star (a star having a spectral radiance of 2.1×10^{-10} lumens/cm^2 and a color temperature of 11,000°K). The test also shows that the output is linearly proportional (within 10%) to the star intensity over the range 0 to 3rd magnitude.

The test was set up at the Harvard Observatory, Harvard, Mass. Dr. Andrew Young of Harvard assisted the Honeywell test group by selecting stars and sighting the PSST through a small reflecting telescope mounted on top of the PSST.

When the star was in the field of view the PSST was moved back and forth, by hand, thus causing the star image to move across the reticle. The output pulses were recorded on a high speed recorder together with a calibration signal. During the test, the P/M tube housing was maintained at +27 ± 2°C. Eleven stars were selected for sighting and 3 to 12 sightings were made over a four hour period. Each sighting netted from 20 to 30 pulses.

The sky background resulted in about 50 millivolts of noise upon which the output pulses were riding. This noise also appeared at the peak of the pulses thus making it difficult to determine the exact pulse height. The frequency response limits (3000 cps) in the Visicorder (paper tape recorder) added to the difficulty of measuring the pulses.

To reduce the data, each set of three pulses was normalized to eliminate the time constant and noise effects and the height of each pulse measured. The average pulse height for each sighting was determined and converted to a voltage using the calibration signal. The apparent magnitude of the star was then calculated using the equation $m = -2.5 \log_{10}$ volts. This equation assumes a 1.00 volt signal for a zero magnitude star. The computer program requires all input data points normalized to 1 volt = 0 magnitude star.

This computer program used was furnished by Dr. Andrew T. Young of Harvard Observatory. Dr. Young assisted Honeywell in the calibration of the PSST and his report is included in this document as Appendix D.

The equations used in the data reduction of the data are:

$$m_i - m_o = -2.5 \log \frac{I_i}{I_o} \tag{7-1}$$

Setting the output voltage $I_o = 1$ for a 0 magnitude star, $m_o = 0$, we obtain:

$$m_i = -2.5 \log I_i \tag{7-2}$$

where

m_i is the calculated magnitude of the ith star corresponding to the measured voltage I_i.

The basic equation used to correct for extinction and color is:

$$\frac{1}{M} m_i = \frac{1}{M} m_{io} + A_o + A_1 (m_{io} - V) \tag{7-3}$$

where M is the air mass of an observation of the ith star whose extra-atmospheric magnitude is m_{io}, V is the visual magnitude of the star, A_o* is the atmospheric extinction and A_1* is a color correction factor.

Using $A_o = 0.3$ and $A_1 = 0$ as given in Appendix D

$$m_{io} = m_i - 0.3\ M \tag{7-4}$$

The sighting time of each measurement was part of the data input to the computer which was programmed to compute the air mass, M, for each measurement. The extra-atmospheric magnitude was then computed from equation (7-4). The means of all data points of each star were then calculated. Using these values, a curve of m_{io} - V versus B - V was plotted. The "best fit" line for these points is given in equation (3), Appendix D as:

$$m_{io} = -0.6 + V + 0.5\ (B - V) \tag{7-5}$$

The extra-atmospheric reading for an AO 0 magnitude star (B = V = 0) would then be

$$m_{io} = 0.6 \text{ magnitude or } 1.74 \text{ volts}$$

To bring the output of the PSST up to the required 5.0 volts, the sensitivity must be increased by 5.0/1.74 or 2.86. This change was made by increasing the P/M tube load resistor to 464K resulting in an output of 4.98 volts for an AD-0 magnitude star.

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* Stars and Stellar Systems, Vol. II, Astronomical Techniques , edited by William A. Hiltner, University of Chicago Press, 1962 - Chapter 8

Substituting these numbers into equation 7-1 we have:

$$m_o - 0 = -2.5 \log \frac{I_o}{5} \tag{7-6}$$

m_o is set equal to 0 magnitude for an I_o = 5 volts and we see that for an AO 0 magnitude star, we now have I_o = 5 and m_o = 0.

We will define a system characteristic, B', which is the response of the PSST, corrected for air mass, extinction, and color. It is referenced to a 5 volt output for a 0 magnitude star. It is the "filter characteristic" of the PSST which is analogous to the (U, B, V) magnitude measuring system common to astronomy. It is obtained in the following manner:

Equation 7-5 gives:

$$m_{io} = -0.6 + V + 0.5 (B - V)$$

If we now change the 162K to 464K, the signal output (in star megnitude) will be

$$\begin{aligned} B^* &= m_{io} - 2.5 \log 2.86 \\ &= -1.74 + V + 0.5 (B - V) \end{aligned} \tag{7-7}$$

This is still referenced to a 1 volt output, i.e., if 1 volt output correspond to a 0 magnitude, a 5 volt output would correspond to the input of a -1.74 magnitude star. However, the 1 volt reference was used only as a convenience for the computer data reduction. Setting m_o = 0 for a 5 volt output gives:

$$\begin{aligned} B' &= B^* - (-2.5 \log 5) \\ &= B^* + 1.74 \\ &= V + 0.5 (B - V) \end{aligned} \tag{7-8}$$

Solving equation 7.1 for I with $m_o = 0$, we have

$$I = I_o \log^{-1} (-0.4)\, B^1 \qquad (7\text{-}9)$$

where I_o is the reference voltage equal to 5.0 volts and I is the system voltage output corresponding to B^1

$$I = 5 \log^{-1} (-0.4)\, B^1 \qquad (7\text{-}10)$$

Table VII-1 shows the values of B^1 and I for the values of V and (B-V) for the eleven stars used in the calibration.

TABLE VII-1

TYPE	STAR	V	(B-V)	B^1	I
A3	β Leo	2.140	+0.090	2.185	0.663
B8	γ CRV	2.600	-0.110	2.545	0.477
GO	η Boo	2.690	+0.580	2.980	0.309
AO	α CRB	2.230	-0.020	2.220	0.643
B3	η UMA	1.860	-0.200	1.760	0.980
Bl	α Vir	0.960	-0.230	0.845	2.280
KO	β Gem	1.150	+1.000	1.650	1.080
KO	α UMA	1.790	+1.060	2.320	0.587
B7	α Leo	1.360	-0.110	1.305	1.490
AO	α Lyr	0.040	0.000	0.040	4.780
FO	γ Dra	2.220	+1.520	2.964	0.325

The values of I and B^1 are plotted in Figure 7.1 and show the linearity of the output voltage with star magnitude as seen by the PSST. Figure 7.2 shows the voltage output vs. the standard visual magnitude compared to the calculated AO and KO lines from the proposal (Honeywell Document 4304-037). The deviations of the stars from the lines is due to the color sensitivity of the telescope. The PSST is less sensitive to the F, G, and

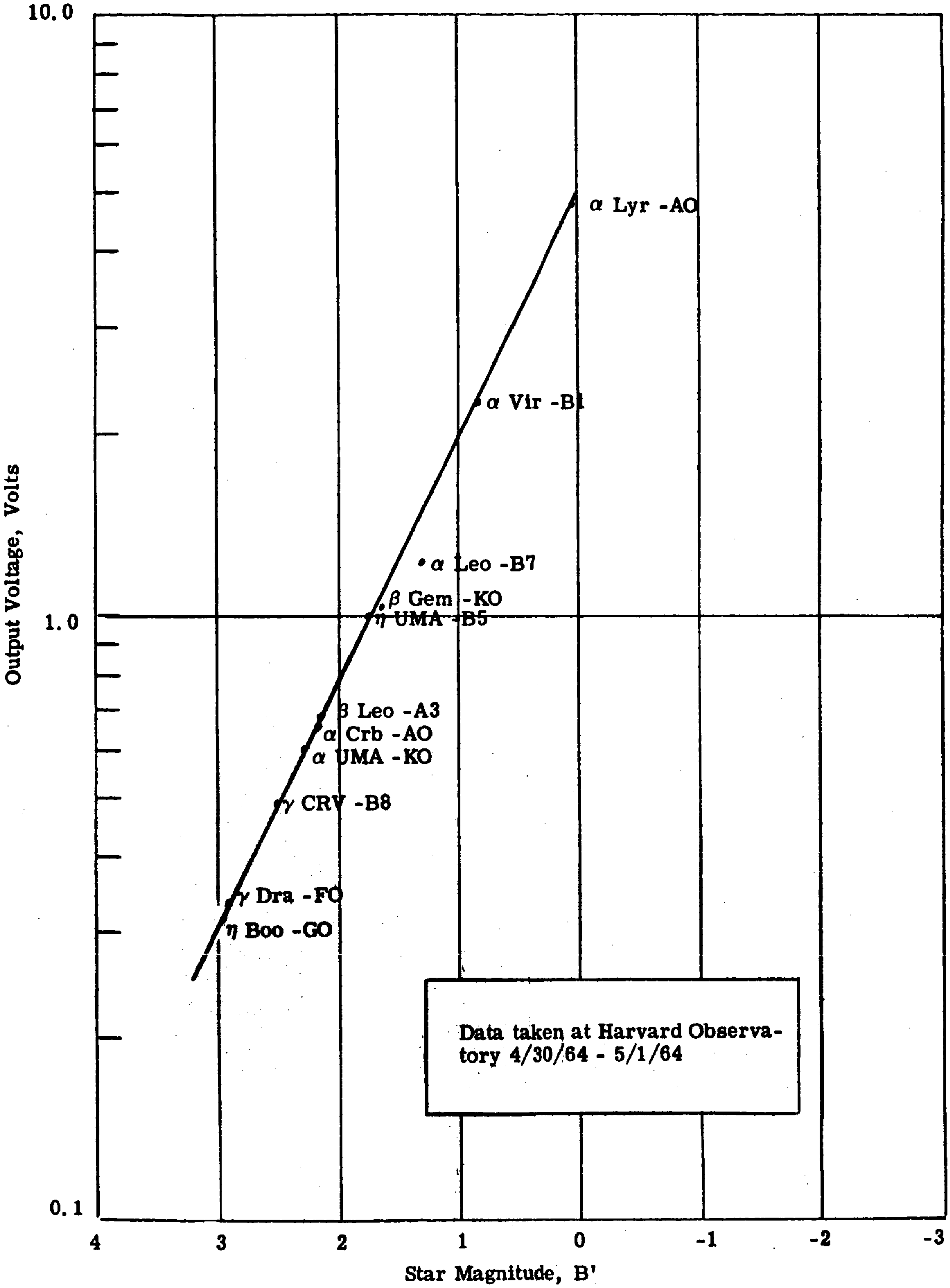


Figure 7.1 PSST OUTPUT VERSUS STAR MAGNITUDE
(Data Corrected for Air Mass and Extinction)

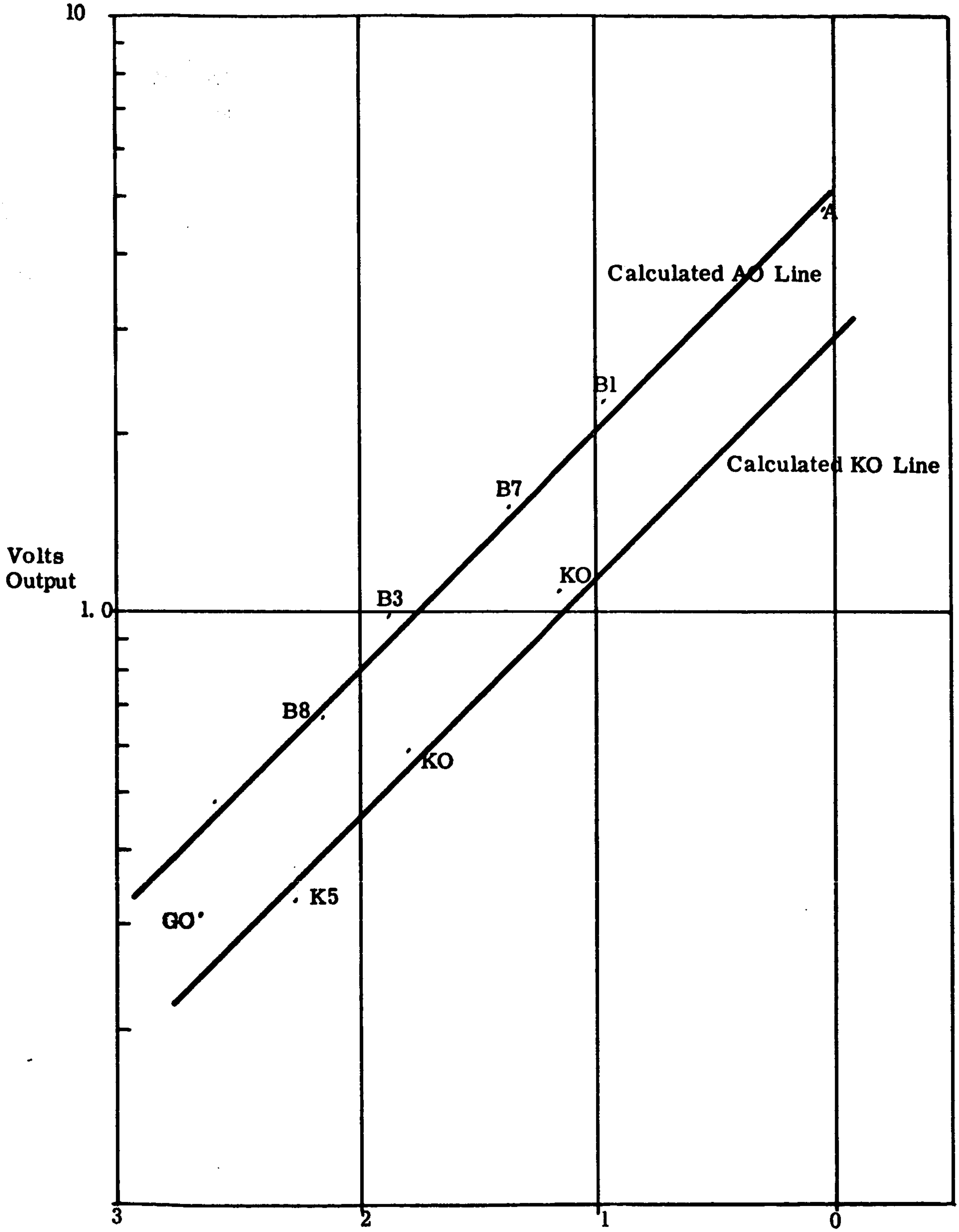


Figure 7.2 OUTPUT VOLTAGE VS. VISUAL MAGNITUDE

K stars than the A and B stars.

During calibration of the instrument 162 K ohms was used as a load resistor. When this value is used, the instrument has an extra-atmospheric output of 1.74 volts or -0.6 magnitude for an AO-O magnitude star. However, 1.0 volt was arbitrarily set as the reference during calibration (the purpose of calibration being to determine the absolute level) and this made an AO-O magnitude star look like a -0.6 star. Therefore, let m_i^1 be defined as the measurements taken during calibration which are relative to a 1.74 volt reference level for O-magnitude.

$$\therefore \; m_i^1 = m_i - 0.6$$

$$\text{or} \qquad m_i = m_i^1 + 0.6$$

Substituting this equation into (7.4), we have:

$$m_{io} = m_i^1 + 0.6 - 0.3 \, M_i$$

The value of M_{io} for a number of sightings of five stars has been determined and compared to B^1 in Table VII-2.

The average error indicated above is due to the uncertainty of the B^1 value. The probable error in B^1 for a 0-magnitude, AO star is 5% and 11% for G and K stars. The data was not sufficient to give a determination of atmospheric extinction and the calibration is based on a "best guess". The estimated probable error and the uncertainty in the predicted signal is discussed in Appendix D.

The spare electronics was calibrated by comparing the output of the spares

TABLE VII-2

TYPE	STAR	M_i	M	m_o	B^1	AVE ERROR
KO	B Gem	1.78	1.314	1.99	1.65	+0.33
		1.93	1.473	2.11		
		1.82	1.928	1.84		
KO	α UMA	2.14	1.060	2.42	2.32	+0.14
		2.24	1.060	2.52		
		2.26	1.090	2.54		
		2.14	1.160	2.39		
		2.16	1.170	2.41		
AO	α CRB	2.17	1.730	2.25	2.22	+0.07
		2.04	1.635	2.15		
		2.11	1.577	2.24		
		2.12	1.312	2.35		
		2.11	1.290	2.34		
GO	η Boo	2.62	1.290	2.83	2.98	-0.13
		2.61	1.200	2.85		
		2.60	1.100	2.87		
		2.60	1.090	2.87		
		2.54	1.090	2.81		
AO	α Lyr	-0.06	1.827	-0.01	0.04	+0.09
		0.02	1.742	0.10		
		-0.09	1.678	-0.04		
		0.08	1.614	0.20		

Table VII-3 is a list of equipment used for the calibration; Figure 7.3 shows the test set-up.

TABLE VII-3

NAME	MANUFACTURER	MODEL NO.	SERIAL NO.
Visicorder	Honeywell	906	D3366E
Amplifier	Honeywell	T6GA	3697E
AC/DC Calibrator	Ballentine	300	D1283S
Oscilloscope	Tektronix	321	D3867E
Power Supply	Kepco	KS60-2M	D4472
Power Supply	Kepco	KS60-2M	D4473
Potentiometer	Rubicon	2736	D4394

to the output of the flight unit electronics when the P/M tubes were exposed to chopped radiation from an incandescent source with a blue filter. The P/M tube load resistor of the spares was set to give the same amplifier output as the flight electronics.

7.5 LABORATORY CALIBRATION

When the PSST was originally calibrated in the Spring of 1964, the unit was taken outside and calibrated against a real sky background as explained in paragraph 7.4. However, a lab star simulator was available in 1965 at Baird Atomic and the PSST was calibrated there. The main disadvantage of calibrating against the actual stars is atmospheric scintillation effects. After the purchase and burn-in of new P/M tubes, fabrication of the telemetry amplifier, and reassembly of P/M subassembly, the PSST was calibrated using the star simulator at Baird Atomic in Waltham, Massachusetts. The star simulator consists of a tungsten-iodine source, color correcting and attenuation filters, and a Davidson collimator. The color correcting filters are used to change the apparent color temperature of the lamp from 3100°K to 6000°K and 10,700°K for G and A stars respectively. The neutral density filters are used to vary the radiation of the simulated stars between 0 and +3rd magnitude in 0.5 magnitude steps.

The flight P/M assembly was first mounted on the flight unit optics and aligned in the collimated beam of the star simulator. An AO-0 magnitude star was set into the star simulator and the output voltage from the PSST amplifier was measured.

On this basis, a resistor was chosen to give near 5 volts out. With the proper resistor wired in the output of the P/M tube, a series of readings were taken for A, G, and M color stars at seven different star magnitude levels.

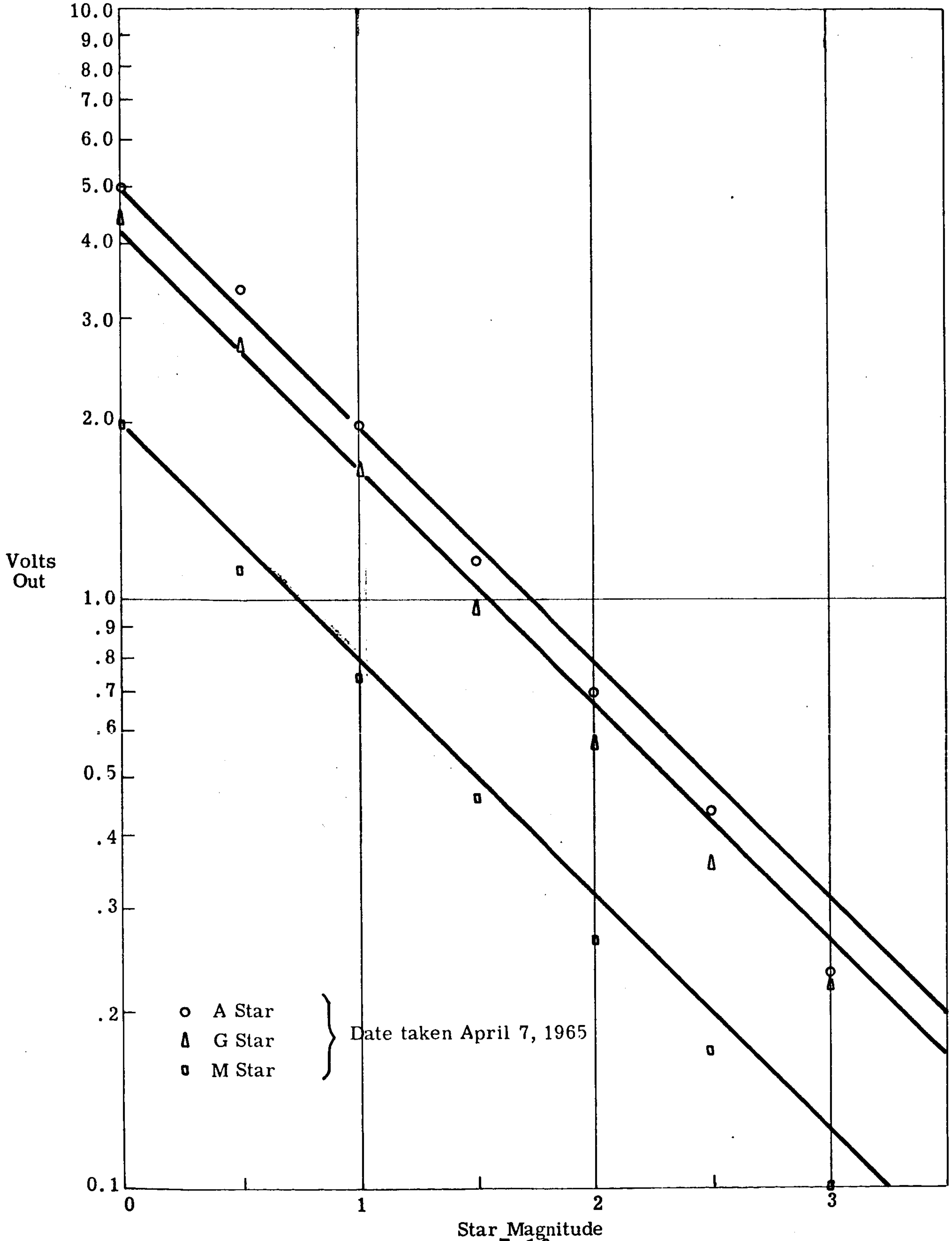
A new resistor was computed on the basis of this second star test to indicate the best resistor to bring these outputs as close to theoretical as possible. Since this computed resistance includes the telemetry amplifier sampling resistor, and in some ways influences the value of the telemetry resistance, a new resistor was determined for the telemetry amplifier to give 5 volt output with 50 microamps input. This telemetry resistance was subtracted from the total resistance required to give the resistance to be placed in the signal circuit.

The spare unit P/M subassembly had not been reassembled by the time the first unit was calibrated, and the Qualification unit optical assembly was used as a transfer standard. The lenses in the Qualification unit are interchangeable with those in the Flight unit, but the folding mirrors in the qualification unit have less transmission than those in the flight unit due to the peeling of the Kanigen coating during fabrication of the mirrors.

The flight P/M subassembly was attached to the qualification optics and a series of readings made for A, G, and M stars. The average of these readings showed that the qualification unit optics had a transmission of 65% compared to the Flight unit.

Figure 7.3 is a graph of the flight unit information. The straight black lines are the computed lines for A, G, and M stars using the Baird Atomic simulator information for the A and G stars and a 3100°K blackbody for the M. The lines were normalized so that the "A" 0 magnitude star gave a 5 volt output. The points marked are the measured data points. The difference between this curve and that sent with the PSST flight unit is that the A, G and M lines are calculated using the simulator spectral curves rather than blackbody curves.

Figure 7. 3 FLIGHT UNIT CALIBRATION DATA



On April 19, 1965 the spare P/M tube and Qualification unit optics were taken to Baird Atomic and calibration runs made against A and G stars to determine the required power supply voltage and on June 10, 1965 the assembled spare P/M subassembly was calibrated. This data is shown in Figure 7.4. The "A" star values are normalized in both cases to give a calculated 5 volt reading for an AO-0 magnitude star.

Discrepancies were noted between the calculated values for the A, G, and M stars and the measured values. These differences were investigated and the conclusions were that the simulated AO star (10,700°K) had a simulated color temperature near 9100°K and a neutral density filter appeared to have been switched during the readings taken April 19, which would account for the low values for the G star in Figure 7.4. The reasons for the difference in slope between the measured values and the calculated values were never determined.

The PSST has an output 20 to 25% greater than 5.0 volts for an AO-0 magnitude star because of the error in the color temperature noted above. Rather than remove the potting from the junction box to change the load resistor, NASA decided to take this change into account in their data reduction program since no stars bright enough to give more than a 5 volt output would appear within the field of view on this particular flight.

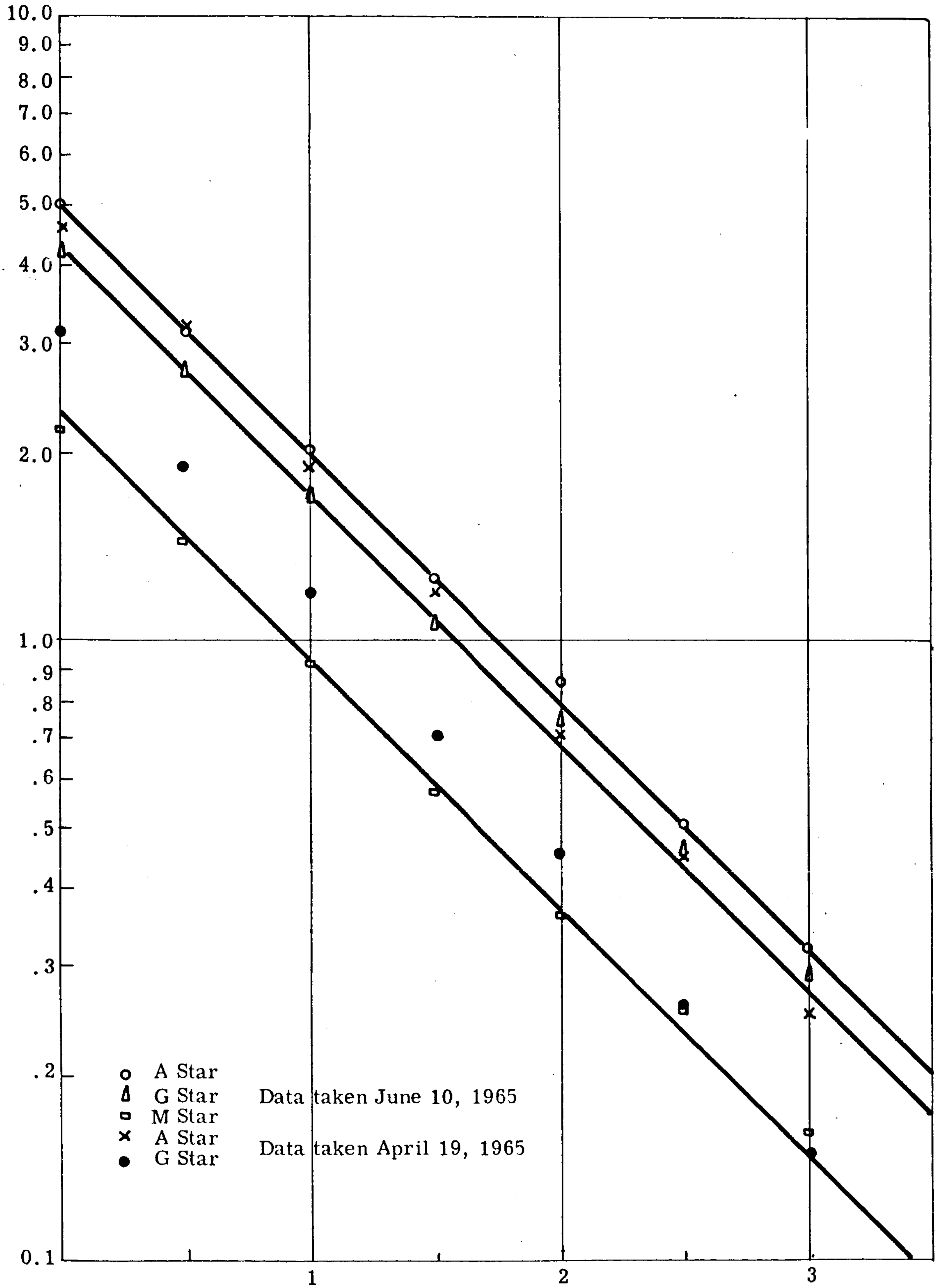


Figure 7.4 SPARE UNIT CALIBRATION DATA

VIII
EARTH SHINE PROTECTION

8.1 P/M TUBE PROTECTION CIRCUITRY

An additional task under the contract was to protect the P/M tube from earth shine radiation, which was defined as radiation equivalent to that of a -15th magnitude star which is visible to a rotating PSST for at least 60 degrees. The proposed method would prohibit the P/M anode current from exceeding 5 microamps from earth shine. Because of space limitations (the optical-mechanical had been designed and fabricated at the time of the study), a shutter in front of the P/M tube was not feasible and methods of switching cathode-dynode potentials were considered.

Two methods were found feasible: switching the second dynode to a voltage at least 25 volts negative with respect to the cathode, and switching the cathode and dynodes to anode potential (ground). The cathode is normally about 300 to 350 volts negative with respect to the second dynode. For positive cathode to second dynode voltages between 25 and 200 volts, the anode current measured 3 to 5 microamps when the P/M tube was subjected to earth shine. A more desirable way would be to switch off the high voltage power supply completely, but the internal time constants of the Pulse supply prohibited this. The next method was to place a switch in the high voltage line between the cathode and the power supply. Reed relays, purchased from Computer Components, Inc. were tested with 5,000 volts across the contacts and found to be satisfactory. Two relays of a type similar to those used in the earth shine protection circuit were subjected to an environmental test which is described in paragraph 8.3. The difference between these relays and those used in the unit was in the coil voltage needed for switching.

The reed relay alone is sealed in a glass capsule in a normally open condition. For normally closed relays, permanent magnets are used. This type of relay was tested but it was found that ferrous materials (tools, supporting structure, etc) placed within 1 to 2 feet of the relays affected the switching performance.

The circuit in Figure 8.1 is the one selected. Three Cairex CL905 HLL cadmium selenide cells are used to sense earth shine. The circuit is designed so that when no light is present on the detectors, the cell impedance is high (<10 megohms) and the relay coil is activated closing the contacts and activating the tube. When the light on one or more of the cells exceeds a preset level the relay is released and the P/M tube is de-energized. Paragraph 8.2 describes the earth shine protection test set up and the results of the tests.

Several types of cells were analyzed as a possible detector for this application. It was desirable to have a cell sensitive enough so that no optics were required, small enough to fit into the sunshield, have a time constant less than 2 milliseconds, and have enough responsivity so that the electronic complexity could be kept to a minimum. A silicon detector met the first three characteristics but required a fairly sophisticated preamplifier because only a small portion of the earth is within the field of view of the detector at the time when switching is necessary. A Clairex CL905 HLL cell was selected. Because it operates as a photoresistor, only power amplification for the relay coil is required. The switching time is somewhat longer than desired, 5-10 milliseconds, but this is sufficient for the 90 degree per second spin rate.

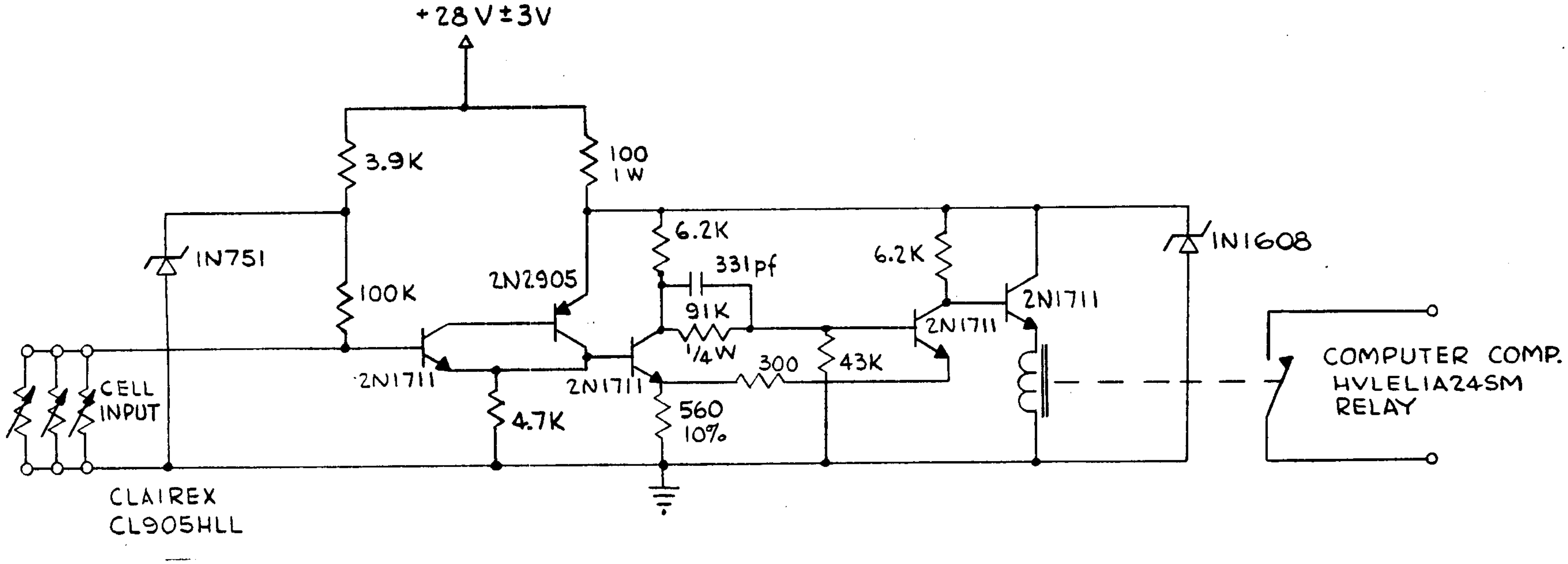


Figure 8.1 SCHEMATIC DIAGRAM, EARTH SHINE PROTECTION CIRCUIT

8.2 EARTH SHINE SIMULATION AND TESTING

Earth shine is defined in the contract work statement as the amount of light equivalent to that from a -15th magnitude star. Astrophysical Quantities by Allen gives 2.65 x 10^{-6} lux (lumens per square meter) as the light from a 0 magnitude star or 2.65 lux for a -15th magnitude star. Lux is used as our measurement unit because the simulated earth shine brightness was measured by a Miranda Cadius light meter which is calibrated in lux.

The sun has an angular diameter of 30 arc minutes which is equal to a subtended solid angle of 0.22 square degrees or 12 lux per square degree. The light meter has a field of view approximately 670 square degrees and illumination from the earth would equal 8000 lux. The maximum illumination of the screen for uniform distribution of light was between 3500 and 4000 lux which would be equal to a -14.3 magnitude star. This gives a safety factor as the Clairex cells have faster response for brighter light levels.

The simulator is a projection screen partially covered by a piece of black felt. The screen is illuminated by a Sylvania sun gun movie lamp which consists of a 200 watt tungsten iodine lamp placed in front of a reflector. The color temperature of this lamp is 3400°K. The PSST was placed on a rotating table in front of the screen as shown in Figure 8.2. A baffle was placed in front of the light to roughly shape the light beam falling on the laboratory as much as possible. The black felt was used for the final shaping of the earth-space intersection.

The D-61 probe ejects the hatch covering the PSST at 40 km and reaches an apogee at 640 km. The earth shine simulator was designed to simulate

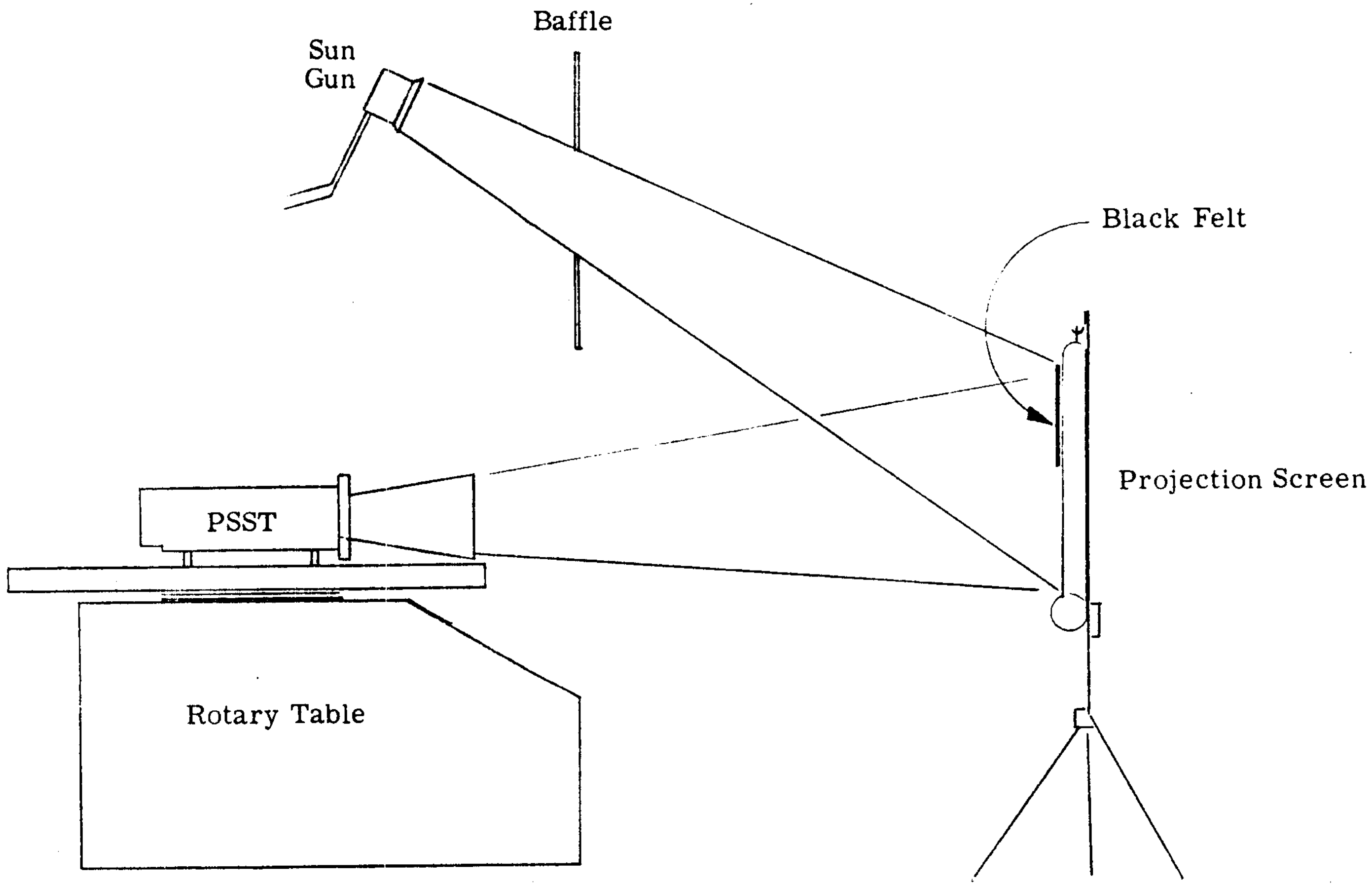


Figure 8.2 EARTH SHINE TEST SET-UP

the portion of the earth seen by the PSST in shape and luminous flux as closely as possible. Three conditions were selected: (1) hatch ejection where the spin axis is approximately 20.5 degrees from the vertical axis at an altitude of 40 km; (2) despin where the spin axis is approximately 20 degrees from the vertical at an altitude of 200 km; and (3) apogee where the spin axis is approximately 16 degrees from the vertical at an altitude of 640 km. Figures 8.3, 8.4, and 8.5 show the configuration of the projection screen for each of these three conditions when the screen is placed 40 inches from the PSST front lens surface.

Three detectors were tested in two configurations: one detector placed at the top of the sunshield with one on each side 20 degrees away; one at the top with one at each side 40 degrees away. The detectors were to be potted into a holder which would be screwed into the face of the fourth convolution face from the rear of the sunshield. An RTV potting compound applied at the outside of the sunshield would ensure a vacuum seal between the inside and outside of the sunshield.

The PSST was placed on a turntable and tests were run for both detector configurations and several spin rates for the three test conditions; namely, despin, hatch ejection, and apogee. A pickoff was placed on the table to trigger the scope and time measurements made between trigger time and relay switching time. The pickoff was placed so that it triggered when the edge of the earth was seen by the detectors. (The P/M tube was not employed during this portion of the test, because of the high background light level.) These times were then converted into angular measurements from the PSST optical axis. The results are shown in Table 8.1

A baffled black box was then placed beside the illuminated screen approximately 6 inches from the earth-space intersection and the PSST with an energized P/M tube was pointed into it. The baffling was used to control test conditions made to prevent stray light from reflecting into and causing saturation of the P/M tube output. The baffled area was larger than the PSST field of view simulating the darkness of space near the edge of the earth.

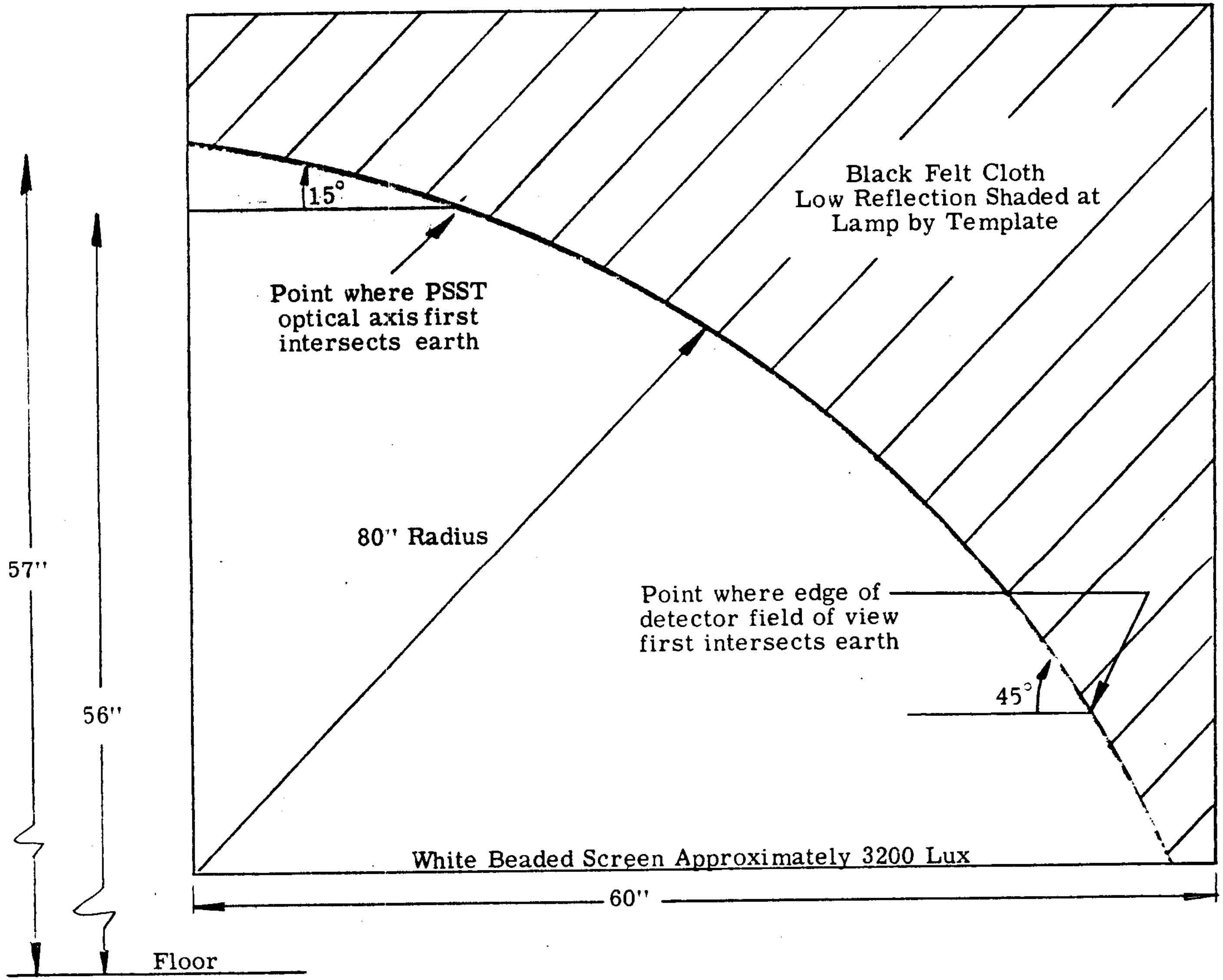


Figure 8.3 EARTH SHINE DESPIN SIMULATION

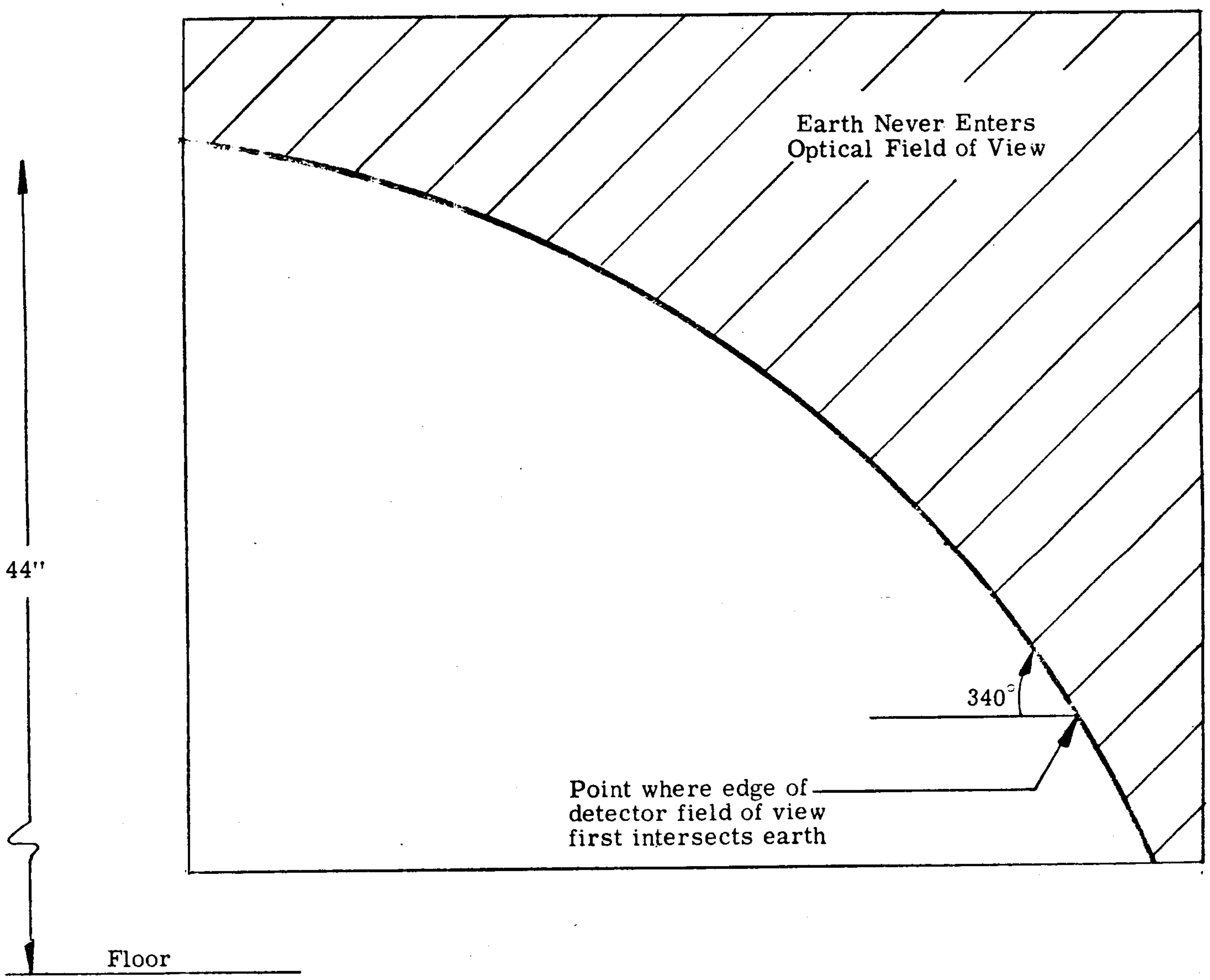


Figure 8. 4 EARTH SHINE APOGEE SIMULATION

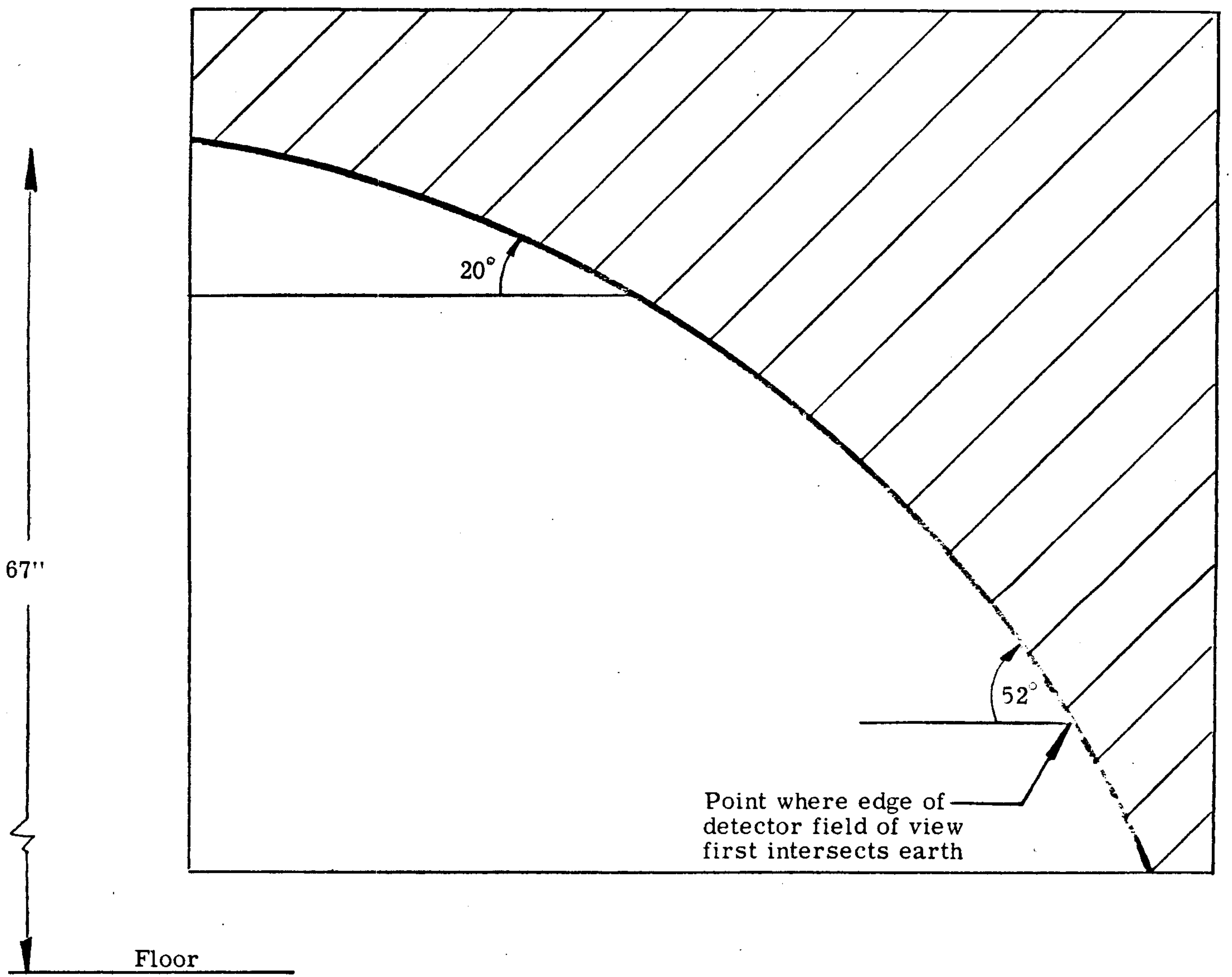


Figure 8.5 EARTH SHINE HATCH EJECTION SIMULATION

TABLE 8.1

Spin Rate (deg/sec)	Detectors ±20° off center line: Time for Trigger (m sec)	Detectors ±20° off center line: Angle from Trigger (deg)	Detectors ±40° off center line: Time from Trigger (m sec)	Detectors ±40° off center line: Angle from Trigger (deg)
30	210	6.3	140	4.2
60	125	7.5	90	5.4
90	190	8.1	70	6.3
120	74	8.8	58	7.0
180	52	12.1	40	7.2
		Hatch Blow-Off		
30	280	8.4	180	5.4
60	160	9.6	105	6.3
90	110	10.0	80	7.2
120	90	10.6	64	7.7
180	60	10.8	48	9.0
		Apogee		
30	560	16.8	550	16.5
60	300	18.0	290	17.4
90	210	18.9	200	18.0
120	164	19.6	160	19.2
180	120	21.6	110	20.0

toward the screen and measurements were made of P/M anode current versus angle as shown in Table 8.2. These angles are also referenced back to trigger position and the point where the optical axis crosses the earth-space border for the despin configuration.

TABLE 8.2

Angle Between Optical Axis and Earth - Space Intersection	P/M Tube Anode Current (microamps)
35.0	1
16.5	2
14.5	3
12.5	4
11.0	5
7.5	10
4.5	20

Several comments should be made about the data in tables 8.1 and 8.2. The angle between the trigger point and the point where the optical axis intersected the earth-space intersection was 36 degrees for the hatch blow-off simulation and 43 degrees for the despin simulation. The optical axis never gets closer than 4 degrees of the edge of the earth at apogee, and this is approximately 90 degrees from the trigger reference. A correction must be made both for the lower light intensity used for simulation (about 0.5), and for the lower color temperature of the simulation source. This amounts to a factor of approximately 4, and an anode current of 5 microamps in space should be equal to 1.25 microamps in the test set up if there was no current caused by background light. However, it was impossible to simulate the space-earth conditions completely, as some light is reflected off the black felt. The simulation condition which gave 2 microamps in the lab is a safe estimate of the same conditions in actual flight which would give a 5 microamp anode current. This means that the P/M tube should be de-energized before the optical axis of the PSST approaches within 16 degrees of the edge of the earth. Table 8.3 shows the relation between the optical axis crossing the earth-space line for various spin rates. The center detector with two others of ±40° was selected as the recommended configuration.

TABLE 8.3

One Detector Centered and Two ±40° Off Center Line

Spin Rate (deg/sec)	Angle Between Relay Actuation and Optical Axis Earth-Space Crossing
Despin	
60	37.6°
90	36.7°
120	36.0°
Hatch Blow-Off	
60	36.7°
90	35.8°
120	35.3°
Apogee	
60	Approximately 50° to closest earth-space intersection
90	
120	

8.3 HIGH VOLTAGE ENVIRONMENTAL TESTS

As part of the Earth Shine Protection Study, two Computer Components Co high voltage relays, part number HVLEL1A24S4, were evaluated. The objective of the evaluation was to determine if the specified relays were capable of performing the required switching functions while being subjected to induced mechanical environments, equivalent to the launch and in-flight environment. The test circuit used in performing the evaluation is shown in Figure 8.5. The square wave generator was used to supply a simulated input to the relay which is provided by a detector and associated amplification circuitry. For the test specimens, the switching threshold was approximately 30 vdc. In flight operation the relay would be activated once every 4 seconds, however a 20 cps switching rate was used during the tests. The high voltage supply used in the test circuit had poor load regulation, which accounted for the lack of a square wave monitoring signal as shown in Figure 8.6. The axes designation for the environmental tests was as shown in Figure 8.7.

The following tests were performed, with the results indicated.

8.3.1 Vibration

Frequency (cps)	Oct/Min	Time	Acceleration "G" 0 to Peak
20-2000	4.0	-	1.5
20-200	4.0	-	4.0
200-500	4.0	-	10.0
500-2000	4.0	-	16.0
550-650	log sweep	18 sec	60.0

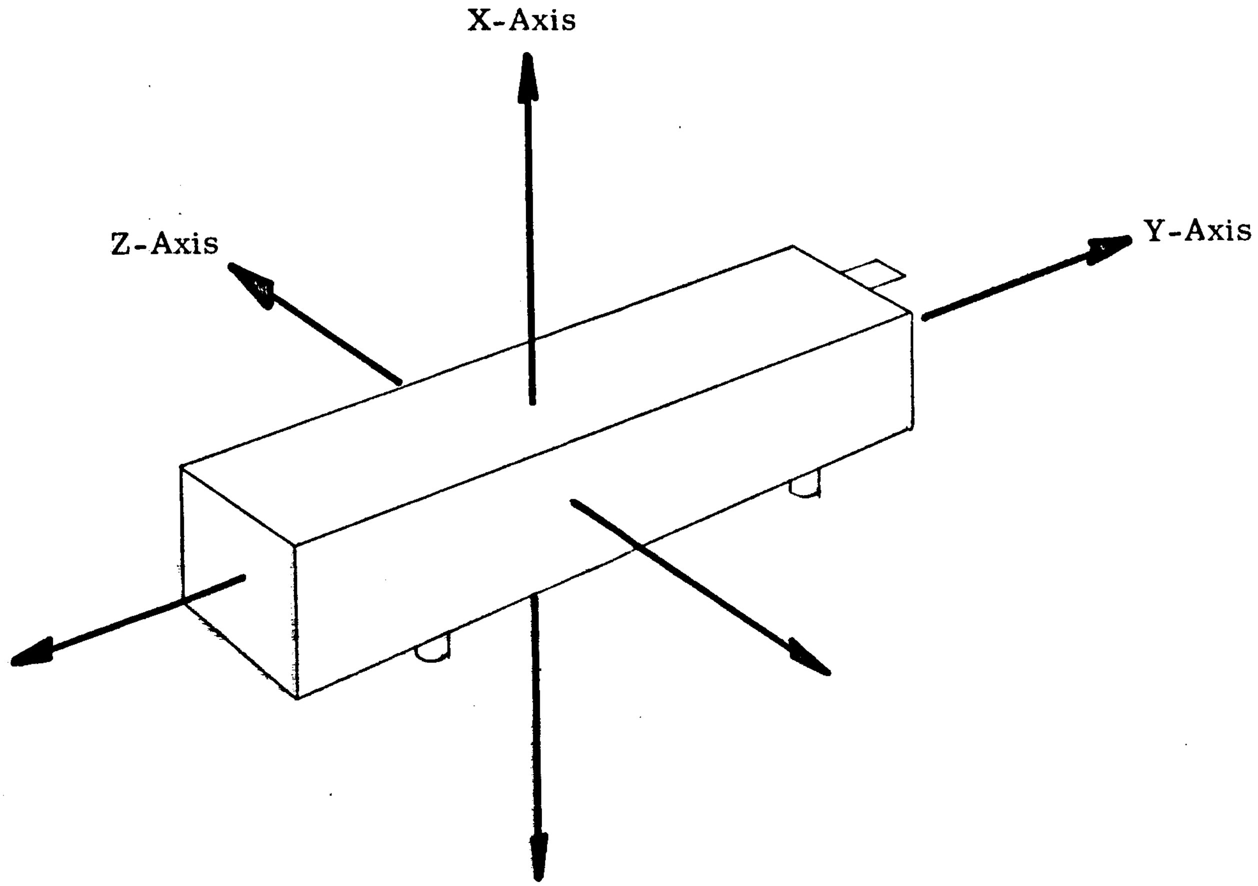
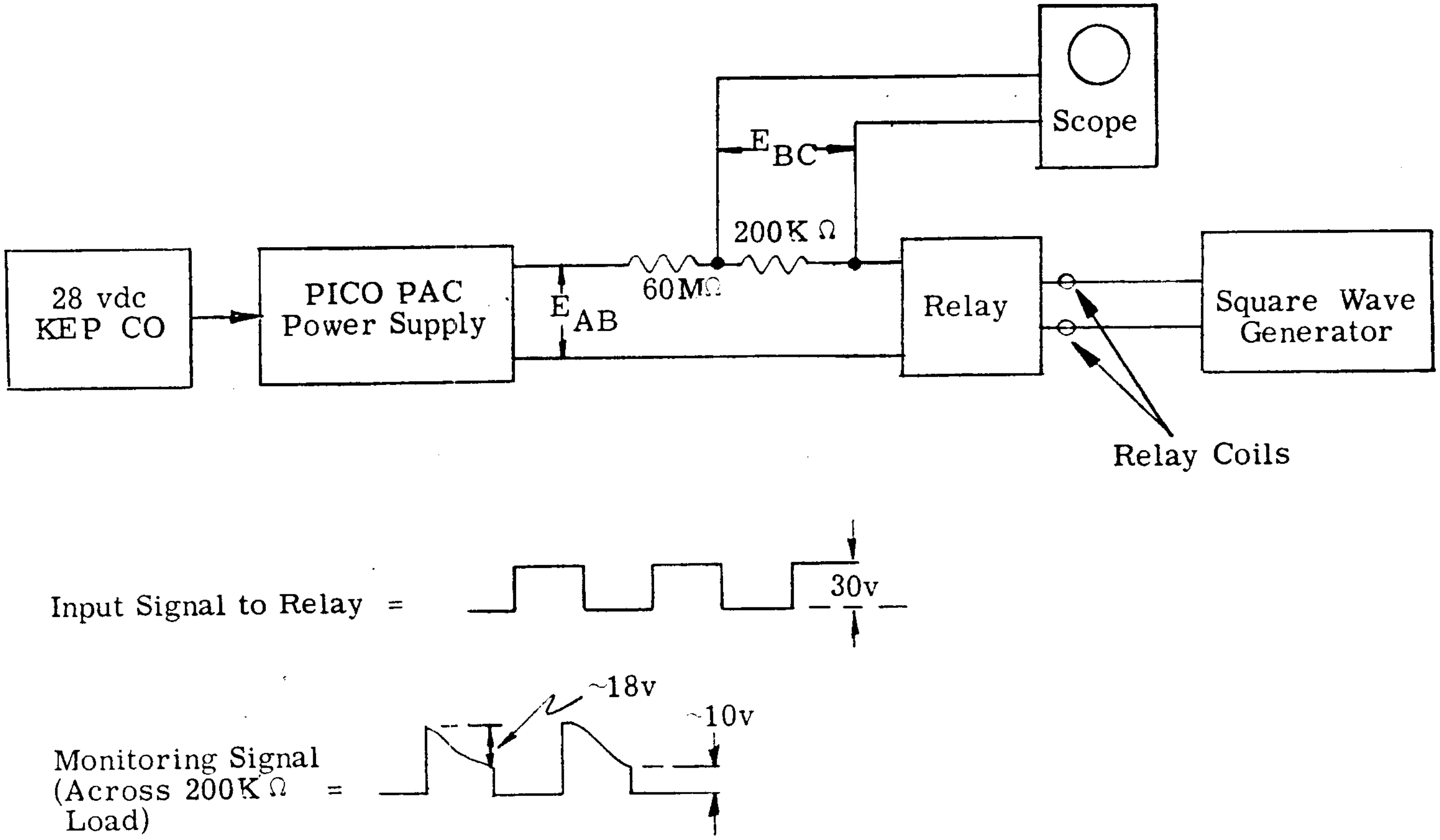


Figure 8.6 ORIENTATION OF RELAY AXIS



E_{AB} = 2650 vdc

E_{BC} = -8 vdc

Figure 8.7 RELAY ENVIRONMENTAL TEST SETUP

Both relays had a resonant frequency of approximately 900 cps in the x-axis as determined by observing gross distortions in the wave shape being monitored on the oscilloscope at this frequency. By adjusting the square wave input actuating the relays and reducing the relay switching rate, the resonant frequency became lower (as switching rate went from 20 cps to 5 cps, resonant frequency went from 900 cps to 850 cps). Increasing the drive voltage to the relay eliminated the resonant frequency.

No resonant frequencies were found in either the y or z axes as determined by monitoring the wave shape displayed on the oscilloscope.

8.3.2 Shock

Both relays were subjected to two 50 G, 15 millisecond impact shocks along the y axis. There was no change observed in the wave shape displayed on the oscilloscope during the test.

8.3.3 Acceleration

Both relays were subjected to 60 G acceleration for two minutes in the x, y, and z axes. There was no change observed in the wave shape displayed on the oscilloscope during the test.

IX

PHOTOMULTIPLIER TUBE BURN-IN

Both the flight and spare PSST photomultiplier subassemblies were calibrated and delivered to NASA in the Spring of 1964. The load resistor values required to give a 5 volt output were 2 to 4 times larger than calculated, but this was not analyzed in detail at the time.

The units were returned to Honeywell to improve the P/M subassembly response to earth shine light conditions, i. e. light reflected off the earth for a period of approximately one second during each revolution of the D-61 vehicle. The amplifiers were reworked to give them the desired transient response but no changes were made to the P/M tubes because the specifications indicated that a maximum anode current of one milliamp could be tolerated.

During recalibration of the spare unit P/M subassembly, a gain reduction of approximately 60% occurred between readings taken just before and just after a weekend. The amplifier was rechecked and found to be operating correctly. The other P/M subassembly gave the same readings as before, which proved that the collimator had not changed; therefore the P/M tube was the cause of the trouble. Both P/M tubes were returned to EMR to be checked. The cathode sensitivity-dynode gain of the flight tube was down to 16% of the specified value given on the manufacturers data sheet and the spare P/M tube was down to 65%. The spare P/M tube was broken during depotting, but tests of the cathode sensitivity and gains of individual dynodes showed that the gains of the last four dynodes had decreased from approximately 2.6 to 1.7, which would account for the degradation factor of 6.

The 1 milliamp maximum current rating of these particular tubes is valid only for some unspecified short length of time, say one millisecond, or less. For periods greater than a few minutes a one microamp d-c current will cause a 2 to 10% gain shift. Brief testing has shown that for a given time the gain shift is a characteristic of each tube. EMR has run tests on further 541 series tubes in 1965 and has found that the gains shift by a factor of 2 to 10 if the anode current is held at 5 microamps for periods of approximately 100 hours. Part of this shift is believed to be inherent in the "venetian blind" dynode structure of the tube itself, which seems to be more susceptible to gain shifts than other dynode structures, such as a squirrel cage or box and grid. Another contributing factor is the Cesium Antimony material on the dynodes. The dynode gain degradation appeared to be permanent and, in the absence of any quantitative manufacturer's test data, two new Ascop P/M tubes were purchased and burned-in for 100 hours at 5 microamps. The acceptance criteria was based on the voltage shift required to maintain a 10^6 gain during a 100 hour period. This maximum voltage was to be less than 500 volts.

The tube was placed in a dark chamber with a No. 4 neutral density filter in front of the sensitive cathode. A lamp assembly was placed 15 inches away from the photocathode, consisting of two 28-volt bulbs. One bulb served as a standard and was turned on only long enough to get a reading. This eliminated the variable of lamp degradation during burn in. Initially the operating lamp was turned on and adjusted to a level that produced a 5 microamp output from the anode of the P/M tube into a 140K load. A surrent sampling resistor was placed in the lamp circuit to monitor the resetting of the lamp. A variable high voltage supply used to operate the P/M tube was initially set at the manufacturer's rated voltage for 10^6 gain.

A record was kept of the output with initial high voltage setting, and the high voltage necessary to return the output to 5 microamps. (Theoretically, with the same light input and same current out the gain had been returned to 10^6.)

This approach is necessary because the field lens illuminates a large portion of the P/M tube face. One difficulty encountered was establishing the starting conditions for the lamp setting because the output dropped extremely fast during the first few minutes.

Figures 9.1, 9.2, and 9.3 show the burn-in history of three P/M tubes serial numbers 5746, 5781, and 6505, respectively. Tube number 5781 was returned to EMR because it failed to meet the acceptance criteria of a 500 volt change in 100 hours. It appears that only part of the gain degradation is permanent as can be seen by comparing Figure 9.1 with Figures 9.2 and 9.3. Tube No. 6505 appeared to be recovering part of its gain during the 16 hour off period during burn-in. When it was checked again two months later, it had an apparent gain of 10^6 at 2550 volts. This indicates it has some of the same characteristics of tube No. 5746. While extensive tests were not run on tubes with a one microamp current, it appears that the decrease in gain will be less than 10% over a 10 to 20 minute period. The PSST will see average currents less than this.

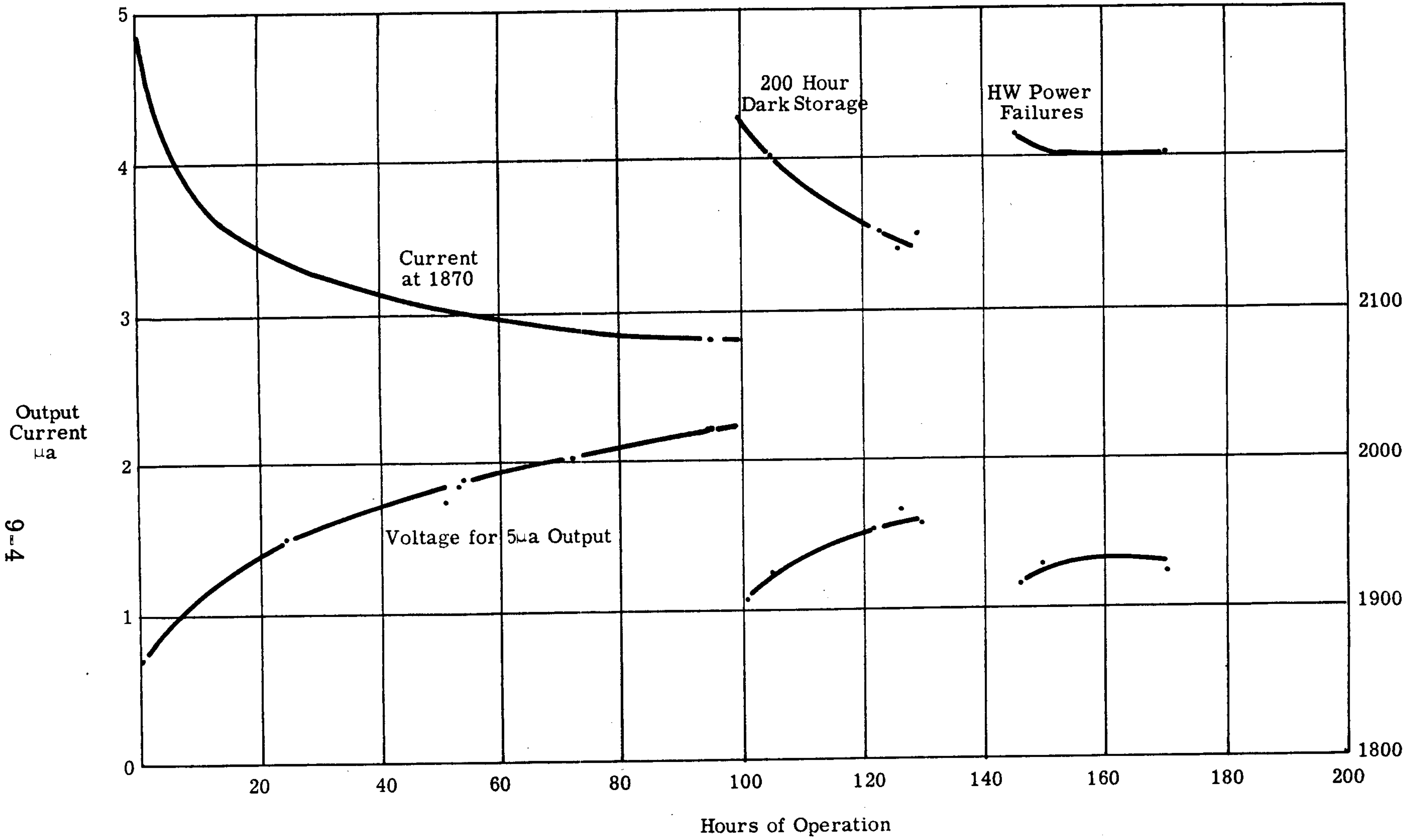


Figure 9.1 BURN IN HISTORY OF P/M TUBE S/N 5746

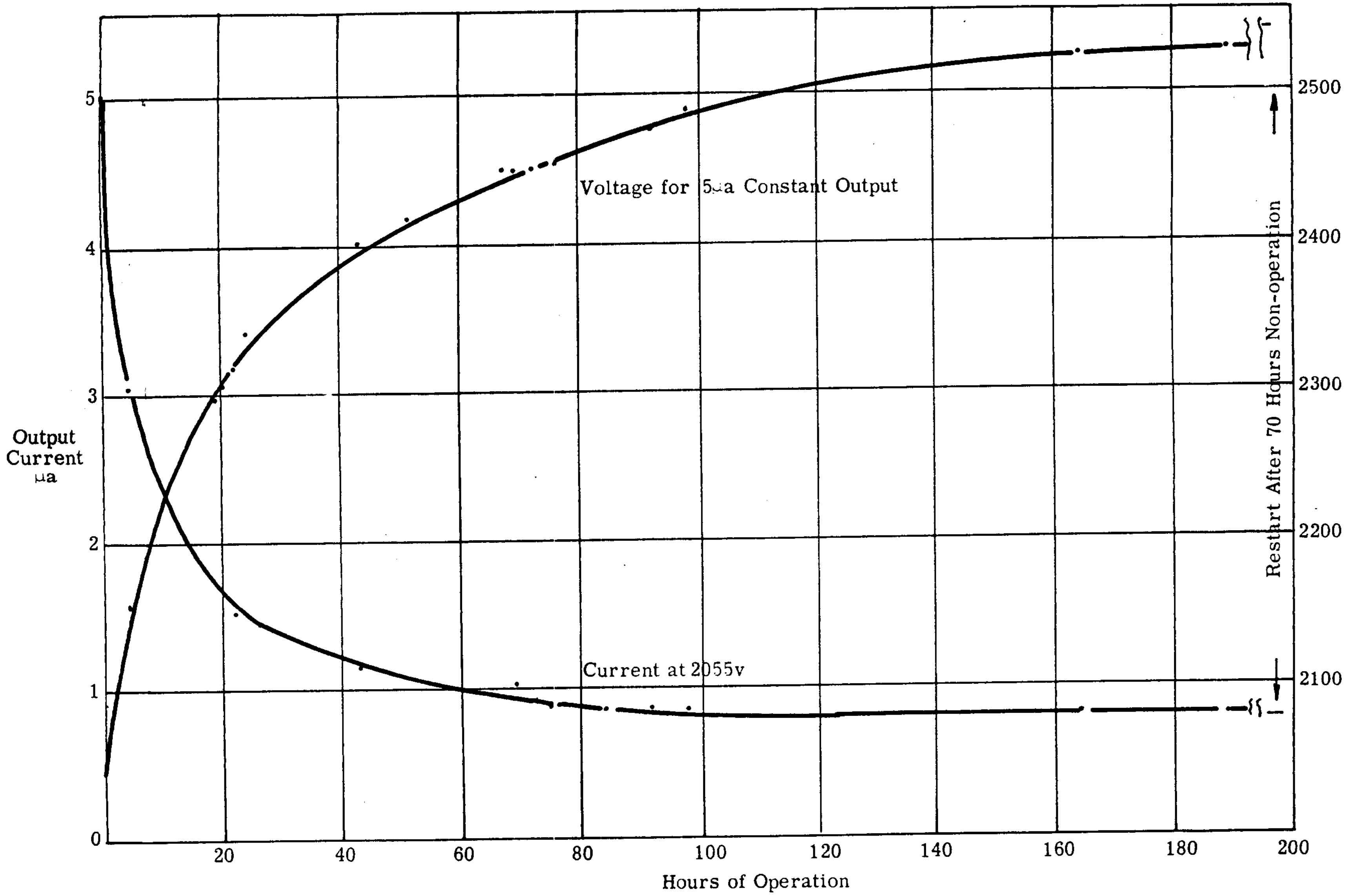


Figure 9.2 BURN IN HISTORY OF P/M TUBE S/N 5781

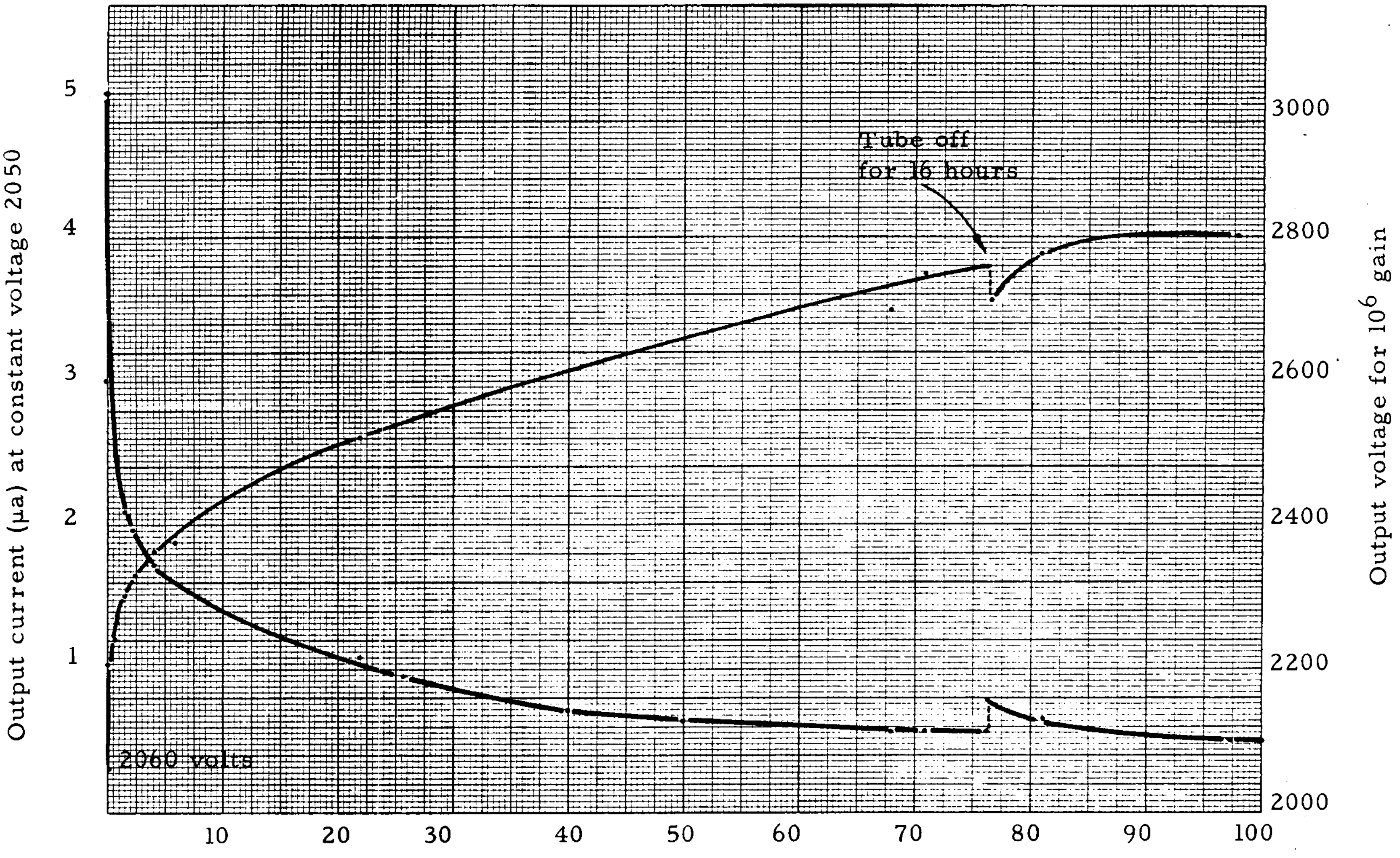


Figure 9.3 **BURN IN HISTORY OF P/M TUBE S/N 6505**

APPENDIX A

INSPECTION AND ACCEPTANCE TEST PROCEDURES

APPENDIX A

INSPECTION AND ACCEPTANCE TEST PROCEDURES

The Inspection and Test Procedures are the NASA approved procedures which were used in the testing of the PSST. NASA Specification L-3300 was used as the basic reference document for these procedures.

SECTION 2[illegible]
PAGE - OF [illegible]
DATE 26 Dec. 1963
QE: H. [illegible]
ENG: J. Dillard
GOVT:

Engineering Q.C.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DI3160A Passively Scanned Star Telescope

REV D 22 April 1964

1 PRIOR INSPECTION COMPLETE

Assemble — 2 IN-PROCESS INSPECTION

3 VISUAL AND MECHANICAL
Before Testing

4 CIRCUITRY

5 PRE-ENVIRONMENTAL TESTS
5.1 Frequency Response
5.2 Telescope Performance
5.3 Bore Sighting
5.4 Field of View Contour
5.5 Stray Light Shielding

6 ENVIRONMENTAL TESTS
6.1 Acceleration
6.2 Shock
6.3 Vibration
6.4 Temperature (non-operating)
6.5 Temperature (operating)
6.6 Pressure
6.7 R. F. Interference

7 POST ENVIRONMENTAL TESTS
7.1 Frequency Response
7.2 Telescope Response
7.3 Bore Sighting
7.4 Field of View Contour

8 POST TEST INSPECTION

Packing and Packaging — 9 PACKING AND PACKAGING INSPECTION

Ship

REVISION RECORD:

A: Rewritten paragraphs: 5.2, 5.3, 5.4, 5.5, 6.5.1, 6.5.2, 6.6.1, 6.6.2, 7.2
All references to Items 4.2 and 4.3 have been changed to 5.2 and 5.3.
Deleted paragraphs: 5.1.

B: Added paragraph: 5.1
Corrected paragraphs: 5.3, 5.4, 6.1, 6.5.2

C: Added paragraph 7.[illegible]

QC FORM 761-3

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A1 Passively Scanned Star Telescope

REV 25 February 1964

GENERAL

A. Scope

ITI 226 describes the inspection and test requirements for the DLG160A1 Passively Scanned Star Telescope.

B. QC Identification and Records

Initiate an End-Item QC Route Tag for each unit, with an "M" series QC number identifying the device and its end-item status. Identify the complete Quality history file for this unit with the end-item QC number assigned.

C. Inspection/Test Acceptance Evidence

1. Upon satisfactory completion of all the inspection/test items that pertain to a given operation, indicate acceptance by signing off or stamping the appropriate box on the QC card.

2. If the inspection or test discloses one or more discrepancies, withhold the acceptance stamp or signature until satisfactory correction or disposition has been obtained, per paragraph D.

D. Inspection and Test Discrepancies

List all discrepancies encountered on an Inspection Discrepancy Notice and route to QE for material review processing. The IDN number consists of the end-item QC# followed by a sequence dash number for each successive IDN issued for that particular device. Register the IDN dash number on the QC card in the space provided: until this entry on the card is followed by acceptance stamp or signature it indicates the WITHHELD status of the device; unless otherwise directed by the cognizant Quality Engineer, also attach a properly filled out WITHHOLD tag to the unit and retain the device in the bonded MRB area pending authorized disposition as indicated on completely signed-off come-back copy of the IDN.

INSPECTION & TEST INSTRUCTIONS

Engineering Q.C.

SUBJECT: DLG160A1 Passively Scanned Star

REV B 25 February 1964

E. Reference Documents

Engineering	Customer
Assy Drwg DLG160A1 Wiring Diagram SK-A-43940	NASA Langley Spec L3300

INSPECTION AND TEST OPERATIONS

1. PRIOR INSPECTIONS COMPLETE

Verify that DLG160A1 sub-assembly inspection and test operations have been satisfactorily completed and evidenced in accordance with applicable ITI's.

2. IN-PROCESS INSPECTION

Inspect the inner-cell assembly per print. Monitor other assembly steps. Inspect alignment of outer-cell sub-assembly.

3. VISUAL AND MECHANICAL Before Testing

Visually inspect unit for workmanship, cleanliness, appearance, etc. Check alignment of assembled unit. The optical axis shall be aligned to the base pads to within .01 degree.

4. CIRCUITRY

Check identification of leads per print.

5. PRE-ENVIRONMENTAL TESTS

All tests of an optical or electrical nature are to be performed at 72 ± 2°F unless otherwise stated.

5.1 Frequency Response

Use an audio frequency sine wave oscillator to drive a GaP Sub Laser. Set the P/M sub-assembly in front of the sub laser and adjust the light intensity to produce a 4 volt peak to peak signal on the output of the P/M sub-assembly at 1000 cps.

Engineering Q.C.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG16_A1 Passively Scanned Star Telescope

REV B 25 February 1964

Vary the frequency from 3 cps to 100 kc keeping the input signal constant. Plot amplitude versus frequency and phase angle versus frequency. The response will be flat within ± 1/4 db between from 50 to 2000 cps. down 1/2 to 1 db at 20 and 6000 kc with a terminal rolloff of 6 db/octave on the low end and 18 db/octave on the high end.

_.2 Telescope Performance

Set up a source using a .002 inch aperture to simulate a star. Set the aperture at the focal point of a collimator. Fasten the unit to the rate table and align the optical axis with the collimator. Rotate the table at 15 RPM and adjust and set the source so that the P/M electronics output is approximately four volts. Take ten output readings and compute the mean of the ten. This test is to be repeated after every environmental test. Any deviation in mean of the output reading greater than five percent is cause for rejection.

Engineering Q.C.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A1 Passively Scanned Star Telescope

REV B 25 February 1964

5.3 Bore Sighting

Use the following procedure to check alignment of all optical elements. Place an optical-plane-parallel on the surface plate and a penta-prism on the plane-parallel. Place a Taylor-Hobson micro-alignment telescope on the surface of the plane parallel. Once perpendicularity is established, remove the plane parallel and pentaprism. The Taylor-Hobson is parallel and perpendicular to the table. Place the PSST with the sun shield facing the Taylor-Hobson. Line up the reticle to the cross lines of the Taylor-Hobson. Measure and record any deviation. The optical axis shall be aligned within .01 degrees of the optical base mounting pads. Also perform azimuth alignment to insure a unit alignment of .01° to the optical base mounting pads.

5.4 Field of View Contour

Mount the unit on the rate table. Set a disc with a pinhole of approximately 4 seconds of arc diameter in the focal plane of the collimator. Set up a chopper in the collimated beam. Measure the parallelism of the vertical lines of the reticle by taking readings of the output of the unit when the image is at the top and the bottom of the narrow verticle slit. The output pulses (5 to 10) which will appear in the narrow slit will be recorded on a Honeywell Visicorder. Measure and record the output when the unit is -3°, -2°, -1°, 0°, +1°, +2°, and 3° off the X axis. The variations in output over the 6° field of view shall not exceed ± 5%.

5.5 Stray Light Shielding

Place the unit on a flat surface. In line with the optical axis of the unit, place a bright chopped source attenuated by a group of neutral density filters which attenuate by a factor of 10^{13}. Using a scope to read output, increase the source brightness until the output pulse is approximately 1 volt. Move the source 26° off the optical axis and remove the neutral density filters one by one until the output pulse height is between 400 millivolts and 4 volts. Record the attenuation factor. Repeat the procedure when the source is 30°, 35°, 40°, 45°, 50°, 55°, 60°, 70°, and 80° off-axis. Plot attenuation versus degrees on semi-log paper.

INSPECTION & TEST INSTRUCTIONS

Engineering Q.C.

SUBJECT: DLG160A1 Passively Scanned Star Telescope

REV ☐ 5 February

6. Environmental Tests

6.1 Acceleration

6.1.1 X Axis

Place unit in accelerometer such that the acceleration will be directed along the negative X axis. (See Figure I). Energize the accelerometer gradually until the unit under test experiences a 26g force along the negative X axis for a minimum of 10 seconds. Gradually reduce the acceleration. When unit comes to rest, remove and replace it so that acceleration will be directed along the positive X axis. Gradually increase the acceleration until the unit experiences a 5g force for a minimum of 10 seconds. Reduce acceleration and remove unit. Repeat paragraphs 6.2 and 6.3.

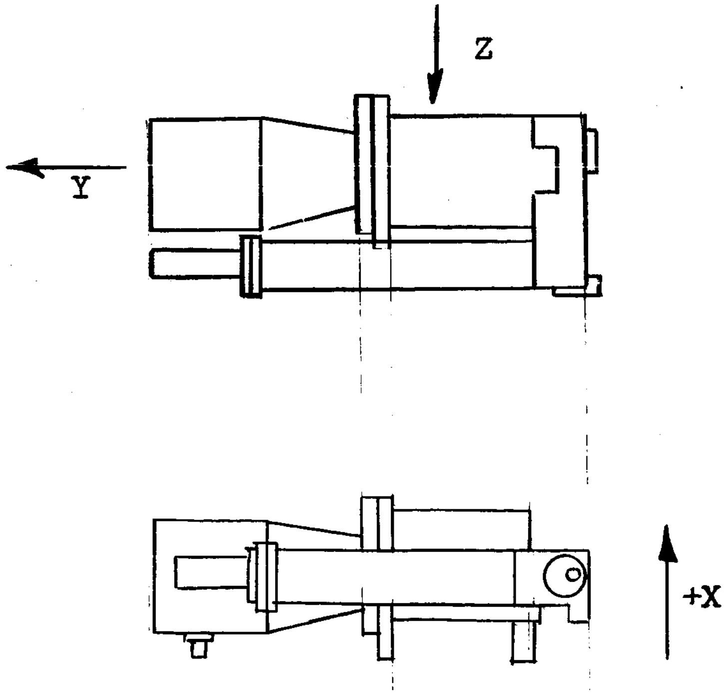


FIGURE I

Identification of X, Y & Z Axes as shown on NASA Dwg No. LD806074.

6.1.2 Y Axis and Z Axis

Mount the unit such that a spin will occur about the X axis. The unit shall endure a spin of 12 rps about the X axis for 150 seconds minimum, where a "G-gradient" of approximately 15 G/inch exists.

After completion of testing, repeat paragraphs 5.2 and 5.3 to insure specification compliance.

6.2 Shock

Mount the unit in the shock apparatus such that the unit will have a 50 "G" shock imposed along the X axis. Use a "memory-scope" to monitor the shock load. The shock shall be be an approximate square pulse of 5 to 15 milliseconds duration.

After completion of testing, repeat paragraphs 5.2 and 5.3 to insure specification compliance.

6.3 Vibration

6.3.1 X Axis

Mount the unit in the vibration apparatus using the designated fixture. Perform vibration according to the following table:

Frequency Range (cps)	Sweep Speed Oct/Min	Time Duration Seconds	Acceleration "G" (0 to peak)
20-2000	4.0	---	1.0
20-200	4.0	---	2.5
200-500	4.0	---	6.5
500-2000	4.0	---	11.5
550-650	Log Sweep	18 Sec.	40.0

Engineering Q.C.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A1 Passively Scanned Star Telescope

REV B 25 February 1964

6.3.2 Y Axis

Remount the unit and use the following table:

Frequency Range (cps)	Sweep Speed Out/ Min	Time Duration Seconds	Acceleration "G" (0 to peak)
20-2000	4.0	------	1.0
20-200	4.0	------	1.25
200-500	4.0	------	3.25
500-2000	4.0	------	5.50
550-650	Log Sweep	18 Sec.	10.00

6.3.3 Z Axis

Repeat 5.3.2 for this axis. After completing vibration, retest the unit according to paragraphs 5.2 and 5.3 assuring specification compliance.

6.4 Temperature (Non-Operating)

Place the unit in test chamber at 20°F and allow to soak for two hours. Remove from chamber and allow unit temperature to stabilize for one hour before performing of further tests. Repeat paragraphs 5.2 and 5.3 assuring specification compliance.

Replace the unit in the test chamber. Adjust the chamber such that the unit is exposed to 120°F. Allow to soak for two hours. Remove unit and allow unit temperature to stabilize for one hour before resumption of testing. Repeat paragraphs 5.2 and 5.3 assuring specification compliance.

6.5 Temperature (Operating)

6.5.1 Frequency Response

Place the P/M subassembly in a temperature chamber set at 100°F. Measure and record the Frequency response at 400, 300, 1600, 3200, and 6000 cps while the unit is cooling to 72°F.

INSPECTION & TEST INSTRUCTIONS

Engineering Q.C.

SUBJECT: DLG160A1 Passively Scanned Star Telescope

REV B 25 February 1964

6.5.2 Blur Circle

Place the unit on an optical bench and heat to 1oo°F. Set a disc with a pinhole of approximately 4 seconds of arc diameter in the focal plane of the collimator. Cover the idsc with a Wratten 78 filter. Turn on the point source nad measure the size of the image in the reticle plance using a filar eyepiece micrometer as the unit cools to 72°F. The angular resolving power shall be less than 36 seconds of arc.

6.6 Pressure

6.6.1 Pressure Differential

Attach vacuum pump and manometer to the cap attached to the sun shield. Decrease internal pressure of the sun shield to less than 1 psia. Measure leak rate for 1/2 hour. Internal pressure shall not increase by more than 2.5 psia.

Increase the internal pressure to 23 psia and measure leak rate for 1/2 hour. Record the results.

6.6.2 Optical Pr ssure Test

Mount the u it on an optical bench. Use a disc with a pinhole of approximately four seconds of arc diameter and cover with a Wratten 78 filter. Place the disc and ilter in the focal plane of the collimater. Attach a vacu m pump and manometer to the unit and reduce the internal ressure to the pressure obtained in the first paragraph of 6 6.1 after 1/2 hour. Turn on the point source and measure the size of the image in the reticle plance using a filar eyepiece micrometer. The angular resolving power shall be less han 72 seconds of arc.

Increase the in ernal pressure to 23 psia and measure the blur circle. If the blur circle fails to meet the seventy-two second spec, further data shall be furnished showing the effect of the increase index of refraction caused by the 23 psia pressure on the blur circle size.

APPENDIX B

QUALITY TEST DATA, FLIGHT UNIT

APPENDIX B

Quality Test Data, Flight Unit

This section gives the results of the tests on the flight unit run according to the procedures given in Appendix A. The specification paragraph numbers refer to the respective test outlined in Appendix A.

AERONAUTICAL DIVISION
BOSTON 35, MASS.

QUALITY
TEST REPORT

REPORT # 1009
DATE 5-5-64
TESTED BY:
APPROVED BY:

DEVICE: DLG 160A1 Passively Scanned Star Telescope

QC # M-028 Serial Series K2

As indicated by accompanying test data, subject device was tested in accordance with ITI 226 and found to be:

☐ Within required tolerances

☐ Not within required tolerances, as noted under COMMENTS, below

TEST DATA:

Spec Par	Test	Requirement	Test Result
5.0	Pre-Environmental		
5.1	Frequency Response		
	45cps-4.5KC	± 1/4db	
	25cps&6KC	1 ± 1/4db	
	below 25cps	6db/octave roll off	Pg. B-3
	above 6KC	18db/octave roll off	
5.2	Telescope Performance	See attached pages	Pg. B-4
5.4	Field of View Contour	See attached repórt	Pg. B-9
5.5	Stray Light Shielding	(Information only)	Pg. B-15
6.0	Environmental Tests		
6.5.1	Frequency Response 100°F		
	400cps ± 1/4db		
	800cps 45cps to		Pg. B-18
	1600cps 4.5KC		
	3200cps ± 1db at		
	6000cps 6KC		

COMMENTS:

Signed ______________ __/__/__

QC FORM 1261-1

AERONAUTICAL DIVISION
BOSTON 35, MASS.

QUALITY
TEST REPORT

REPORT # 1009
DATE 5-5-64

DEVICE: DLG 160A1 Passively Scanned Star Telescope

QC # M-028 Serial Series K2

TEST DATA: CONTINUED:

Spec Par	Test	Requirement	Test Result
6.5.2	Blur Circle 100°F	36 sec. max.	22 sec.
6.6.1	Pressure Differential		
	a) 14 psia 1/2 hr	2.5 psia decrease	11.9 psia (2.1 psia decrease)
	b) 8 psia 1/2 hr	2.5 psia increase	8 psia (no measureable increase)
6.6.2	Blur Circle 23 psia	72 sec.	24 sec.
7.0	Post Environmental Tests		
7.1	Frequency Response	Repeat 5.1	Pg. B-19
7.2	Telescope Response		Pg. 7-3
7.3	Bore Sighting		
	a) From 0° reference established during pre-environmental testing	36 sec.	app 25 sec.
7.4	Field of View Contour		Pg. B-9
7.5	Spectral Response		Pg. B-20
	Reference Information		
	a) weight		19.5 lbs.
	b) alignment		
	1. elevation		0°
	2. azimuth		3' 38"

COMMENTS:

Signed ____________ __/__/__

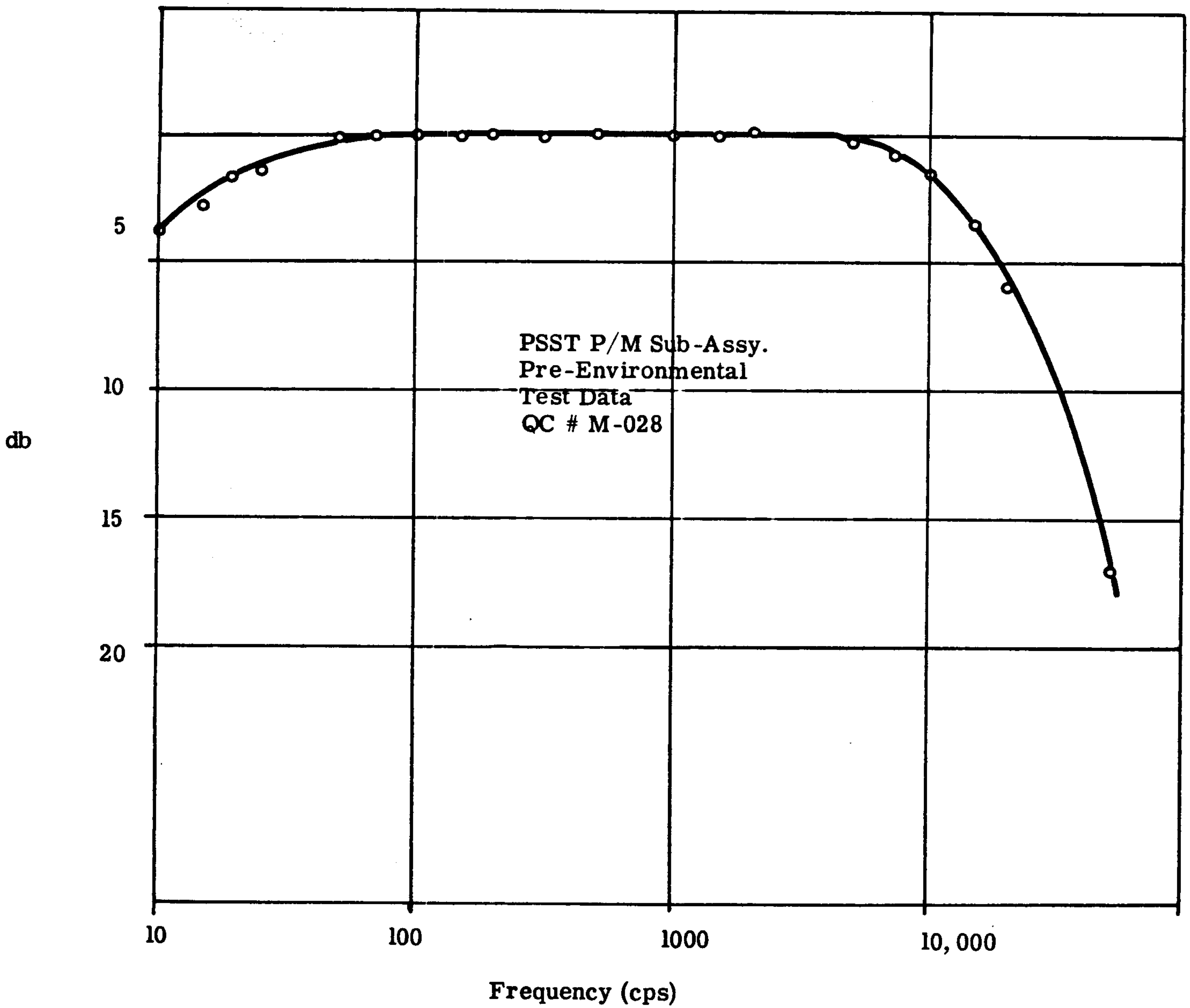

PSST P/M Sub-Assy.
Pre-Environmental
Test Data
QC # M-028
db
5
10
15
20
10
100
1000
10, 000
Frequency (cps)

Figure 1

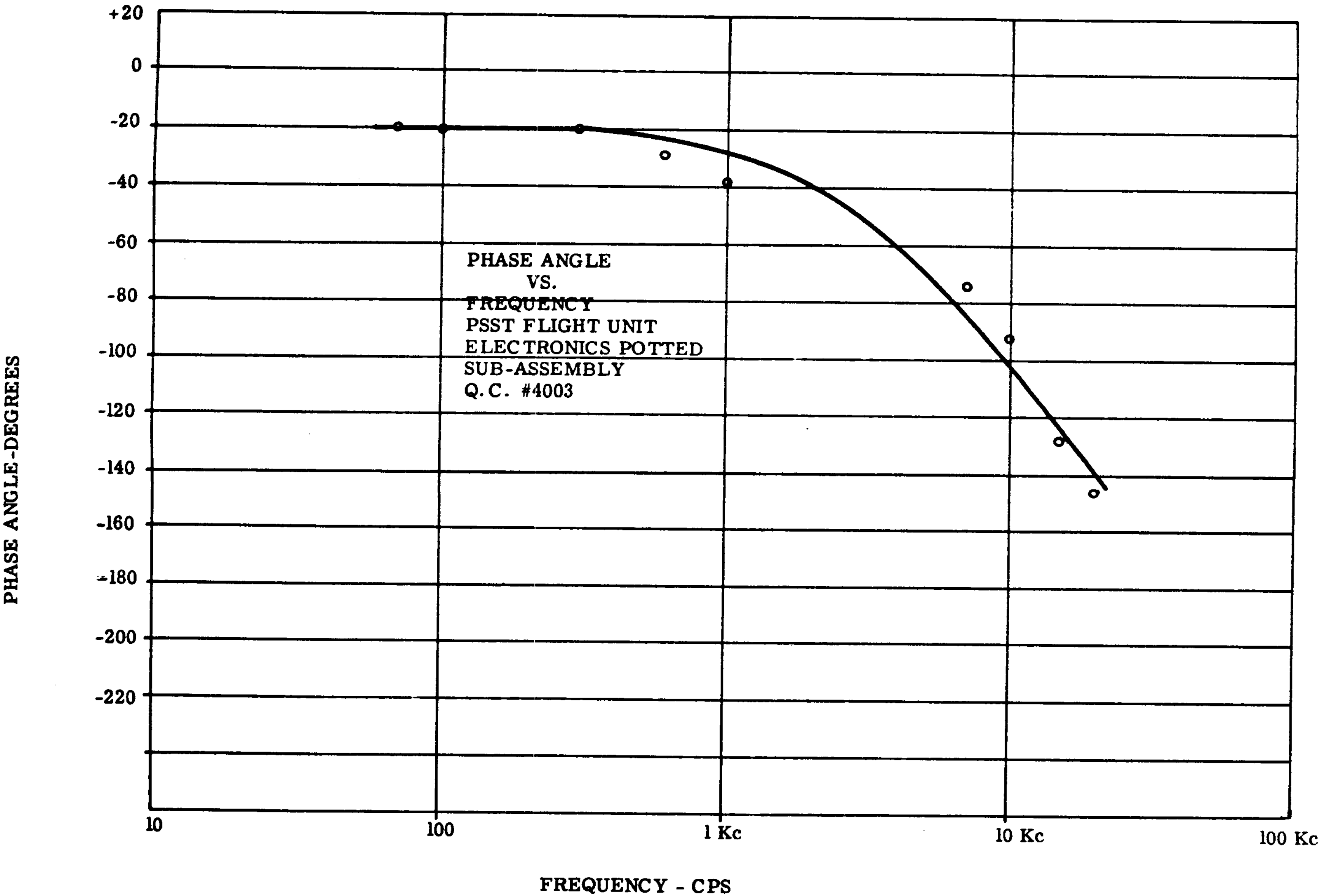

PHASE ANGLE-DEGREES
+20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
PHASE ANGLE
VS.
FREQUENCY
PSST FLIGHT UNIT
ELECTRONICS POTTED
SUB-ASSEMBLY
Q.C. #4003
10
100
1 Kc
10 Kc
100 Kc
FREQUENCY - CPS

Figure 2

EXPLANATION OF PICTURES

The pictures on pages B-5 through B-8 show the output pulses after each environmental test. The test was run as described in paragraph 5.2 on page A-4 except that a picture of the output was taken rather than take 10 measurements. The signal to noise is great enough so that the pulse heights can be accurately measured and we have the added advantage of a permanent record of the original test data.

FIELD OF VIEW

The field of view test was run as outlined in Appendix A. During early runs, data could not be repeated from run to run partly because the rotating table top did not remain level in either axis (parallel or perpendicular to the optical axis) whenever a new gauge block setting was used to give a new vertical angle (γ). This angle varied from -3 degrees to + 3 degrees according to the rotating table during the field of view test and measurements recorded before and after each run at a specified vertical angle (γ). The parallel correction was measured at right angles to the optical line of sight axis. These corrections appear in Tables BI and BII.

During data reduction, the reference values at the positive end differed from the measured values more than could be accounted for by measurement errors. In reviewing the test method, the cause was found to be that the wrong sine block value was used. The sine block chosen was for a level table but, in actuality, the table was purposely tilted -5 degrees. The sine block value was computed for setting the table at 0 degree and moving in 1 degree steps between -3 degrees and +3 degrees. The sine block value needed for +1 degree would therefore be 0.1396 inch, i.e. 8 inches (moment arm of sine bar) x sin 1 degree. Since the sine table was tilted -5 degrees, the steps were +2 degrees and +8 degrees with respect to the table. This was necessary so that the unit would not have to be turned around on the rotary table top. The gauge blocks require positive values. The amount that the table should have been tilted is 8 x (sin 6° - sin 5°) or 0.1390 inch. This is approximately 0.006 degree. The extent of this error is shown in the fourth column of Tables BI and BII.

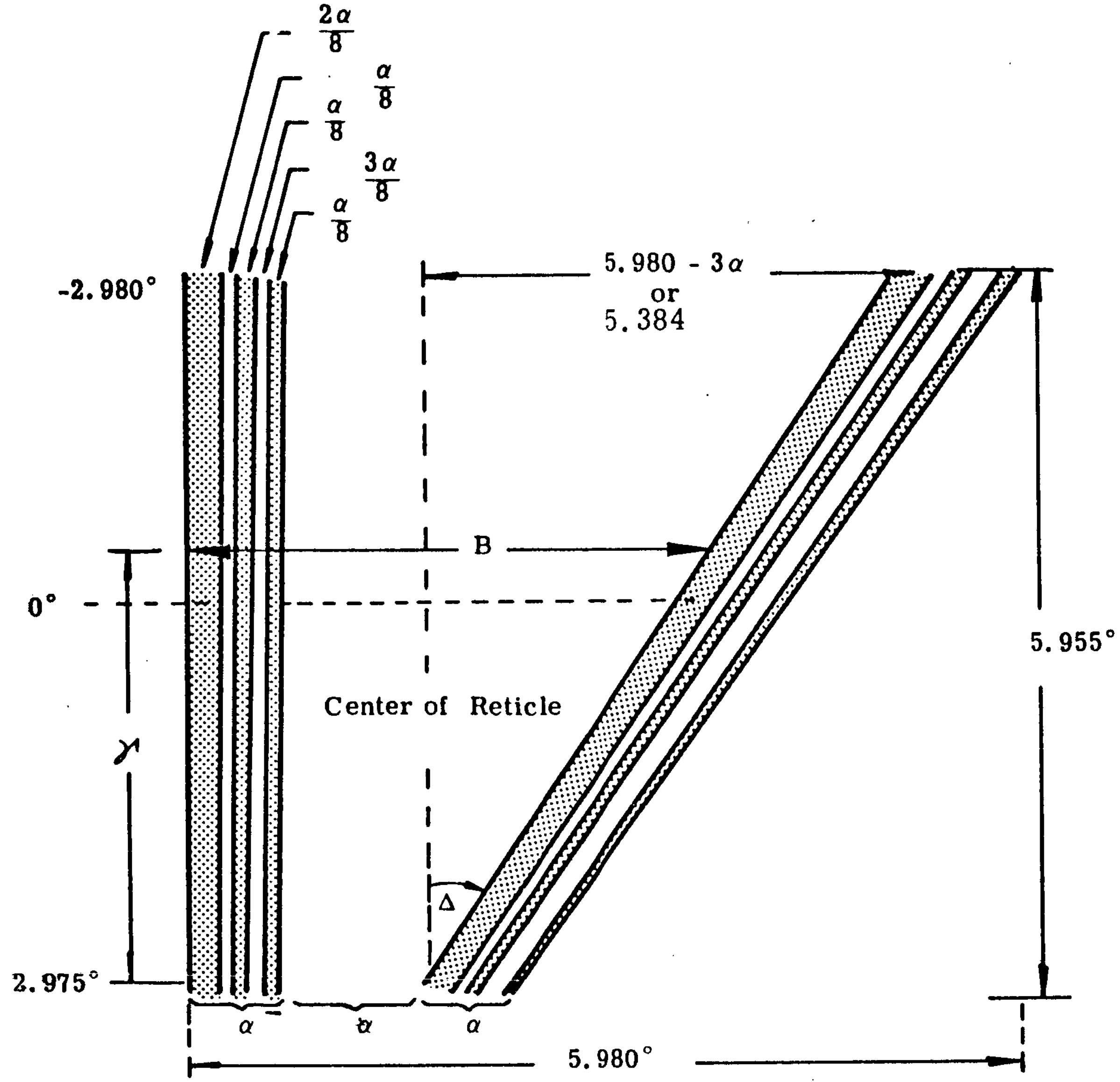
These corrections, added to the reference value, are the angle of the optical axis of the PSST with respect to the optical axis of the collimator.

Tables III and IV give a further correction for astigmatism and distortion. These numbers are the best estimates calculated from the design data of the optical system.

The figure on page B-10 shows the measured reticle. The 5.955 degree and 5.980 degree dimensions were obtained by raising and lowering the sine bar until the output pulse heights were half of their normal value. The equation on this page was used to calculate B' in Tables V and VI. The measured values were obtained by measuring the distance between pulse groups for each and multiplying by the measured table speed.

The rms errors of the field of view for pre-environmental measurements and post-environmental measurements are 0.0060 degree and 0.0033 degree or 0.1% and 0.05% respectively. This is greater than the tolerance shown on the reticle specifications (0.04%) but this may be accounted for by the errors associated with the measuring instruments and procedures.

The vertical field of view was measured by raising the sine bar until the star image was half way off the end of the end of the slits.



$\alpha = .1985°$

$3\alpha = .5955°$

$$\tan \Delta = \delta = \frac{5.346}{5.940} = .9000$$

$$B = 2\alpha + .9000\,(2.980 - \gamma)$$

MEASURED RETICLE PATTERN

B-I

Corrections for Measurement of (Verticle Reticle Angle)

Pre Environmental

Ref. Value	⊥ Corr	∥ Corr	Sin Corr	Corrected Value
-2.958	-.001	+.002	-.002	-2.959
-2.000	-.001	+.001	-.002	-2.002
-1.000	-	-	-	-1.000
0.000	-	-.001	-	-.001
1.000	-	-.001	+.006	+1.005
2.000	-	-.001	+.012	+2.011
2.950	-	-.004	+.019	+2.965

B-II

Post Environmental

Ref. Value	⊥ Corr	∥ Corr	Sin Corr	Corrected Value
-2.950	-.001	+.001	-.002	-2.952
-1.992	-.001	-	-.002	-1.995
-.992	-	-	-	-.992
+.008	-	-	-	+.008
+1.008	-	-.002	+.006	+1.012
+2.008	-	-.004	+.012	+2.016
+2.958	-	-.004	+.019	+2.973

B-III

Pre Enviromental

α	B	Astigmatic and Distortion Correction	B'
-2.959	5.742	.017	5.759
-2.002	4.881	.009	4.890
-1.000	3.979	.005	3.984
-0.001	3.080	.001	3.081
+1.005	2.175	.002	2.177
+2.011	1.269	.003	1.272
+2.965	.411	.002	.413

B-IV

Post Enviromental

α	B	Astigmatic and Distortion Correction	B'
-2.952	5.741	.017	5.758
-1.995	4.872	.009	4.881
-0.992	3.971	.005	3.976
+0.008	3.072	.001	3.073
+1.012	2.168	.002	2.170
+2.016	1.263	.003	1.266
+2.973	.403	.002	.405

B-V

Pre Environmental F.O.V.

Corrected γ	Calculated B (B')	Measured B	Diff. (Calc-Meas)
-2.960°	5.759°	5.755	+.004°
-2.002	4.890	4.891	-.001
-1.000	3.984	3.994	-.010
-.001	3.081	3.091	-.010
+1.005	2.177	2.180	-.003
+2.011	1.272	1.272	-
+2.975	.413	.407	+.006

B-VI

Post Environmental F.O.V.

Corrected γ	Calculated B (B')	Measured B	Diff.
-2.952	5.758	5.753	+.005
-1.995	4.881	4.881	-
-0.992	3.976	3.977	-.001
+0.008	3.073	3.075	[illegible].002
+1.012	2.170	2.167	+.003
+2.016	1.266	1.261	+.005
+2.973	.405	.40[illegible]	+.004

TEST REPORT

STRAY LIGHT SHIELDING

The sunshield test was run by placing neutral density filters in front of the P/M tube and measuring the output when the PSST was observing the radiation of a solar simulator, then removing the neutral density filters and measuring the output at off axis instrument positions.

Neutral density filters = 16 were placed between the P/M tube and field lens assembly. The PSST was then exposed to the radiation from a carbon arc solar simulator. The output was 0.5 volts. Measurements were then made with a neutral density filter = 2 for angles of 20° to 42° and with no filters for angles between 50° and 60°.

In order to verify these numbers, the instrument was pointed directly at the sun on a bright day. There is a difference of approximately 10^4 between the calculated value of neutral density filters (10^{12}) and the actual filters (10^{16}) required to attenuate the direct rays of the sun to give a 0.5 volts PSST output, and it was assumed that the filters do not attenuate the stated amount in the wavelengths of interest. The points on the attenuation curve (Figure 2) were adjusted to take this into account.

Figure 3 shows a plot of the PSST P/M tube output versus various N.D. numbers. The N.D. numbers were obtained by using various combinations of from one to five neutral density filters (i.e., either three N.D. filters = 1 or one N.D. filter = 3, both of which give an N.D. sum = 3). The conclusions of this curve are that the filters attenuate the stated amount whether one or five filters are used. This does not correlate with the above data and indicates that the sunshield might have a better attenuation than indicated.

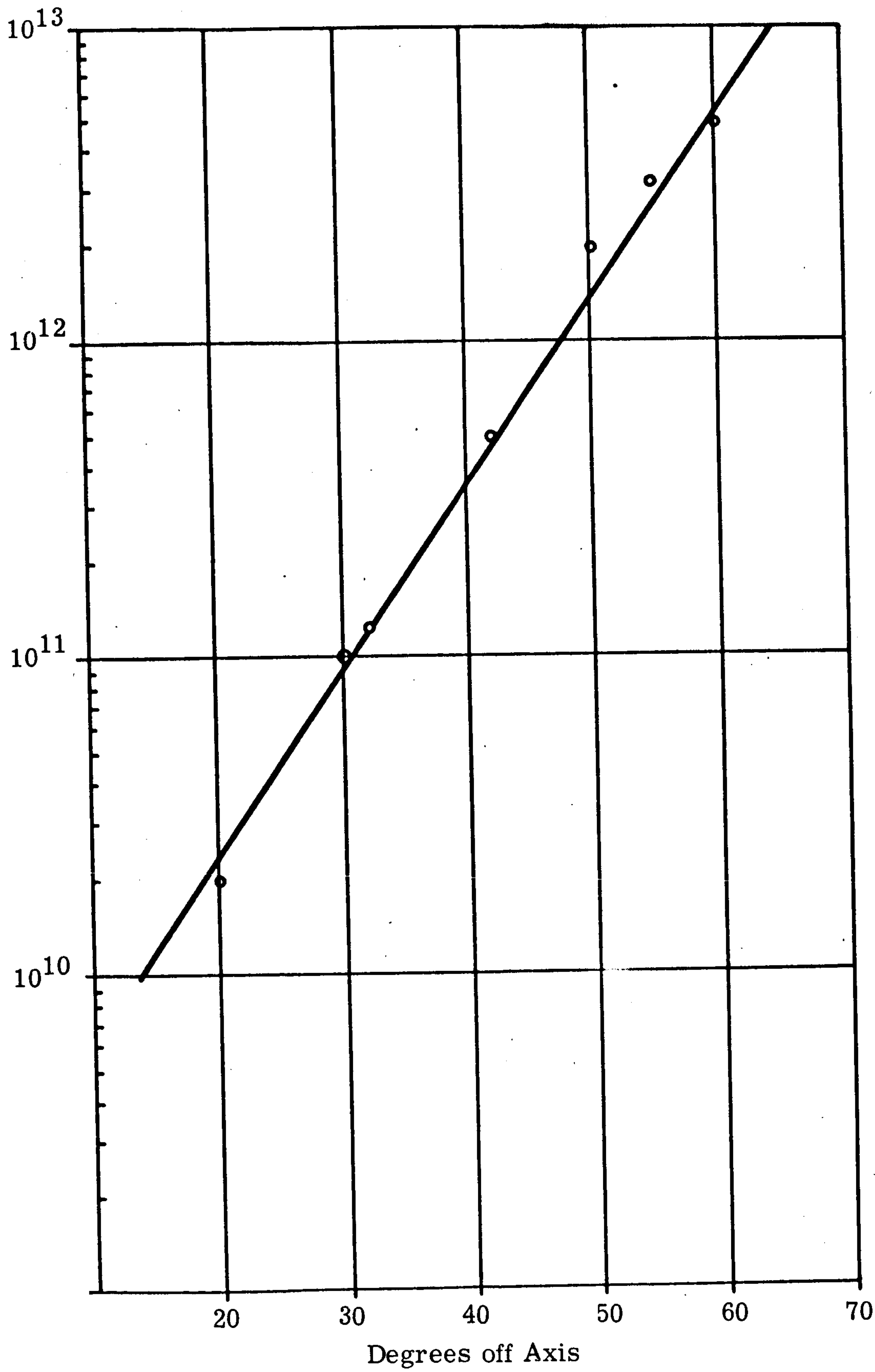


Figure 3 PSST SUNSHIELD ATTENUATION VERSUS DEGREES OFF AXIS

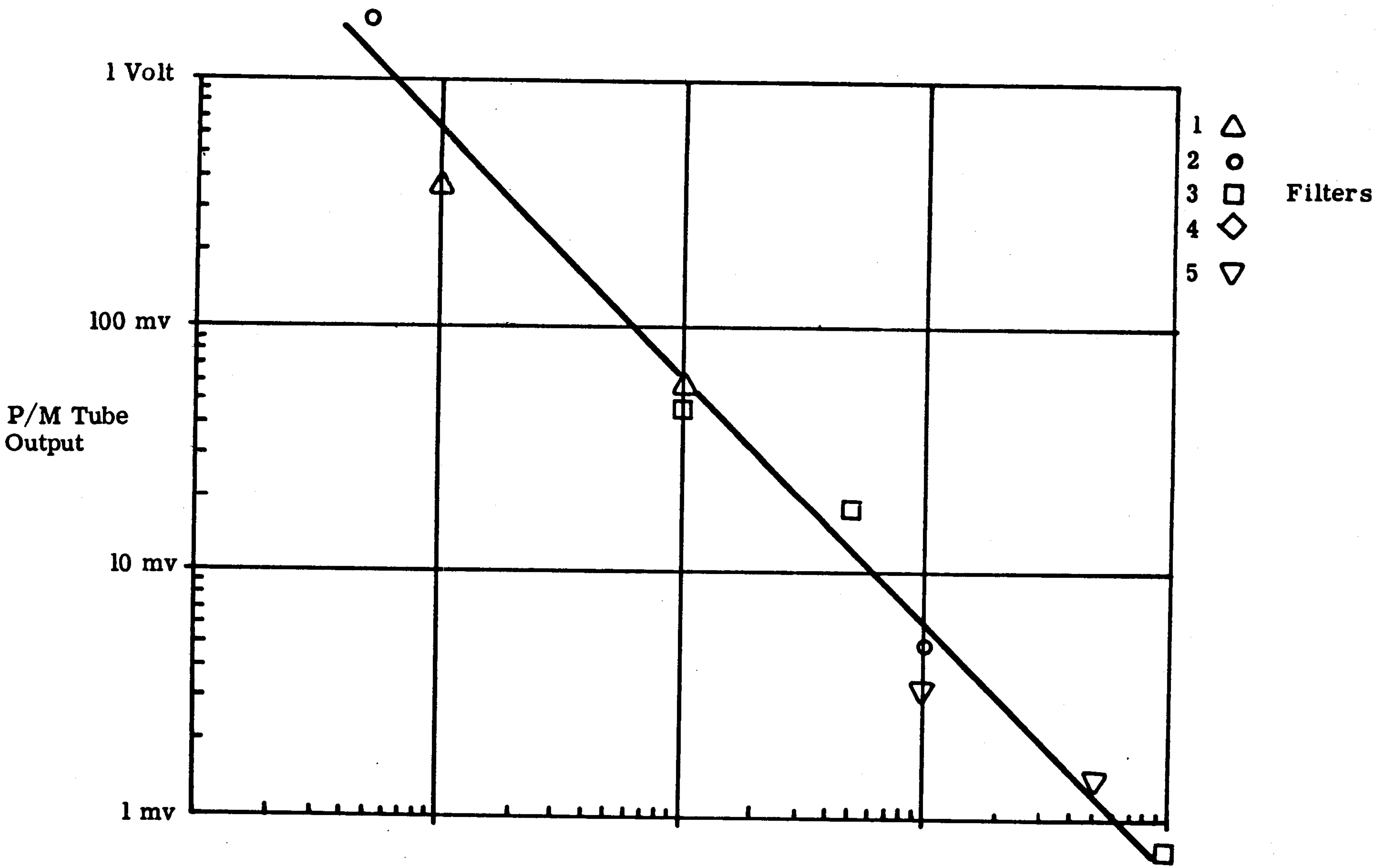


Figure 4 PLOT OF PSST P/M TUBE OUTPUT WITH NEUTRAL DENSITY FILTERS PLACED IN FRONT OF TUBE FOR ATTENUATION

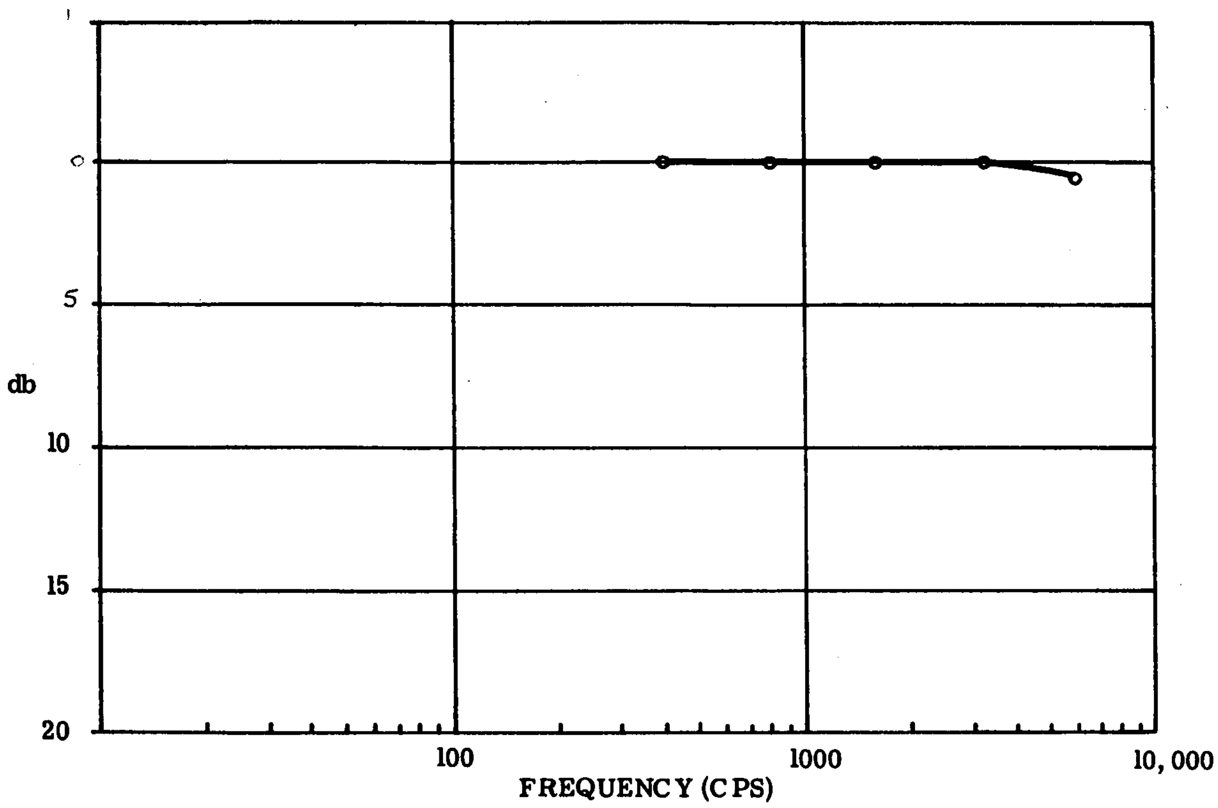


Figure 5 PSST P/M SUB-ASSEMBLY FREQUENCY RESPONSE AT 100°F

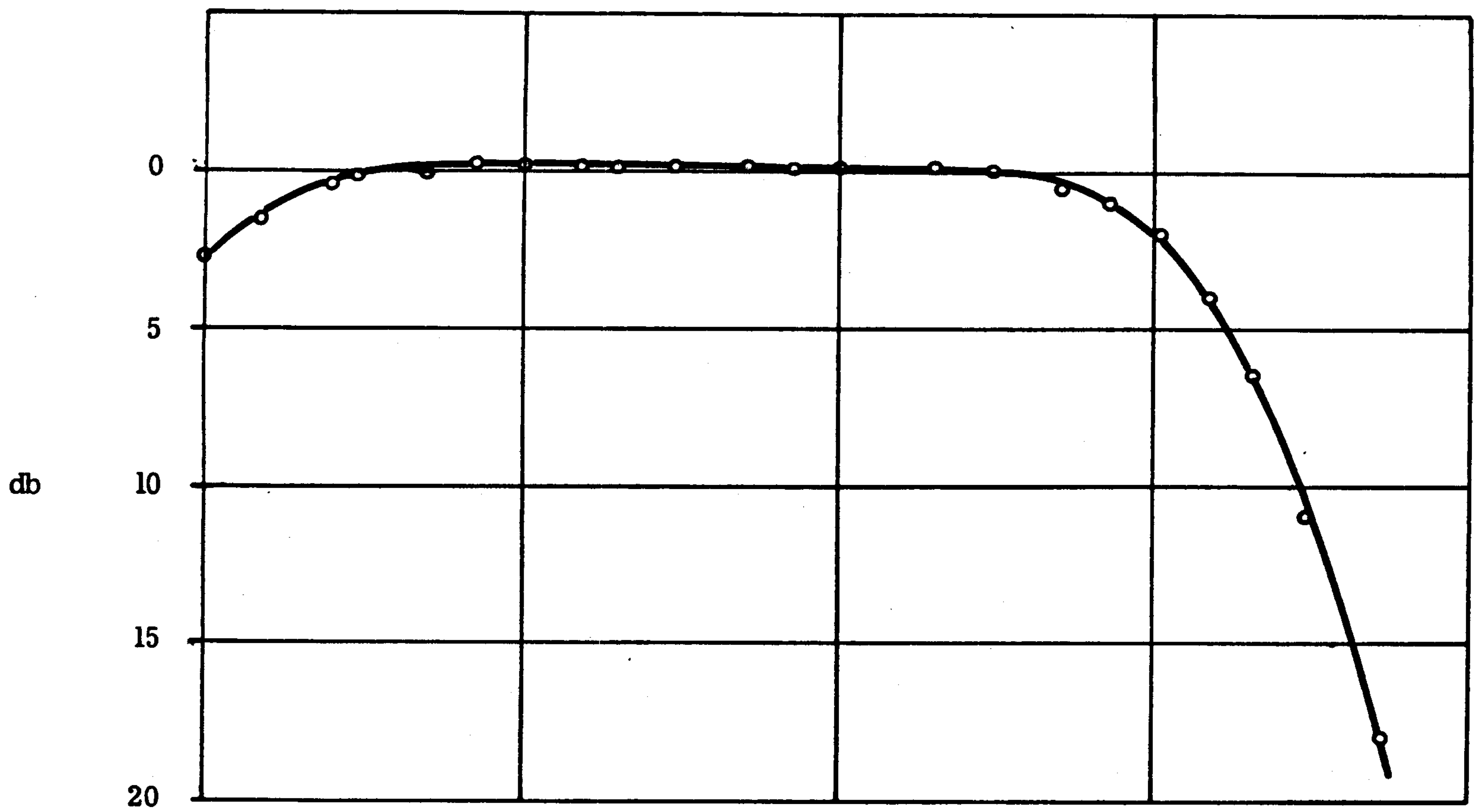


Figure 6 PSST P/M SUBASSEMBLY POST ENVIRONMENTAL TEST DATA, QC # M-028

SPECTRAL RESPONSE

The relative spectral response of the flight unit's optics, P/M subassembly, and combined unit are shown in figures 7, 8, 9. The spectral response data points for the P/M tubes were taken from curves for each individual tube supplied by the tube manufacturer, EMR. The spectral characteristics of the optics were measured using a monochrometer P/M tube and a calibrated source. The curve for the complete unit was obtained by combining the tube curve with the optics curve.

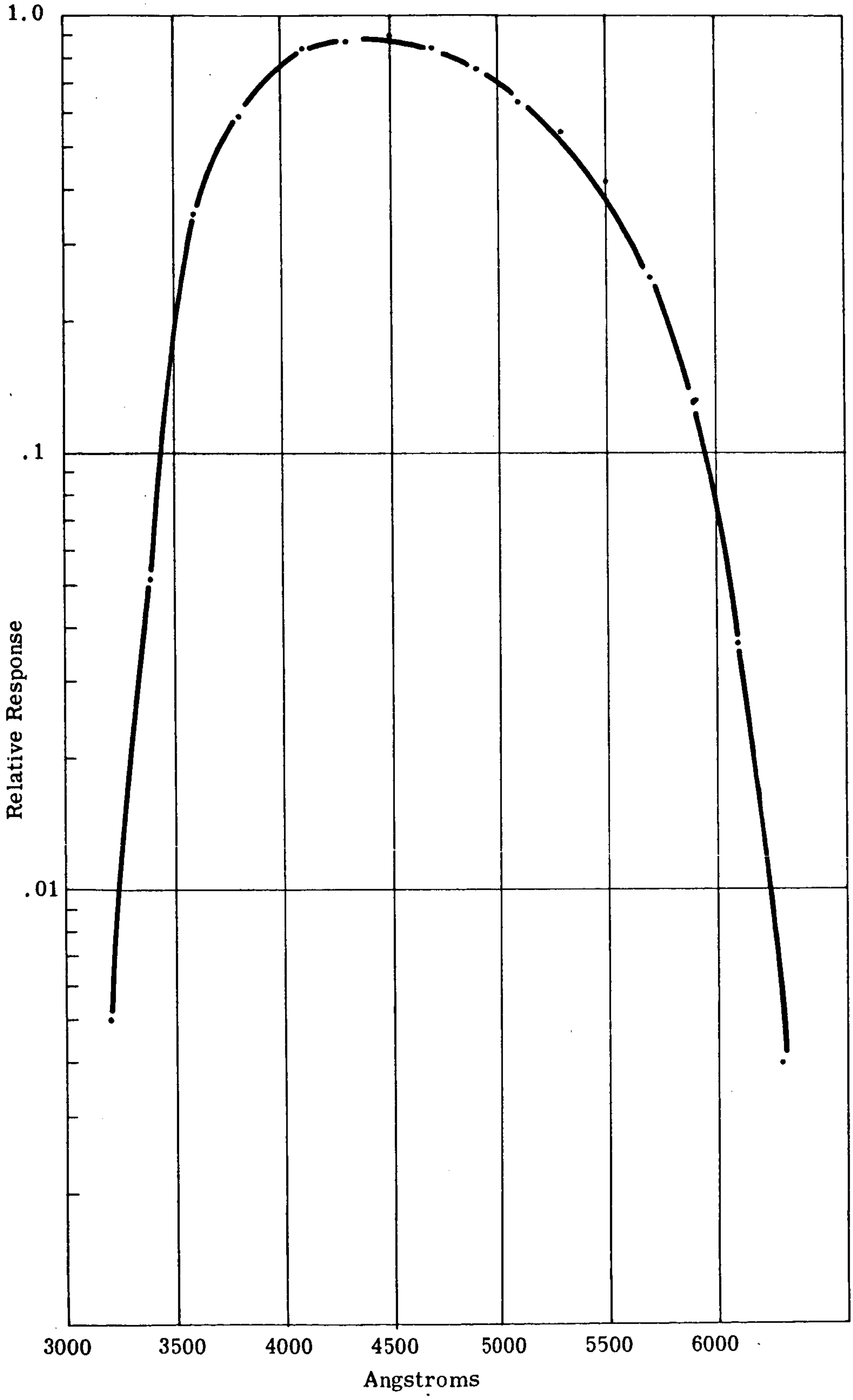


Figure 7. SPECTRAL CHARACTERISTIC PSST SYSTEM FLIGHT UNIT

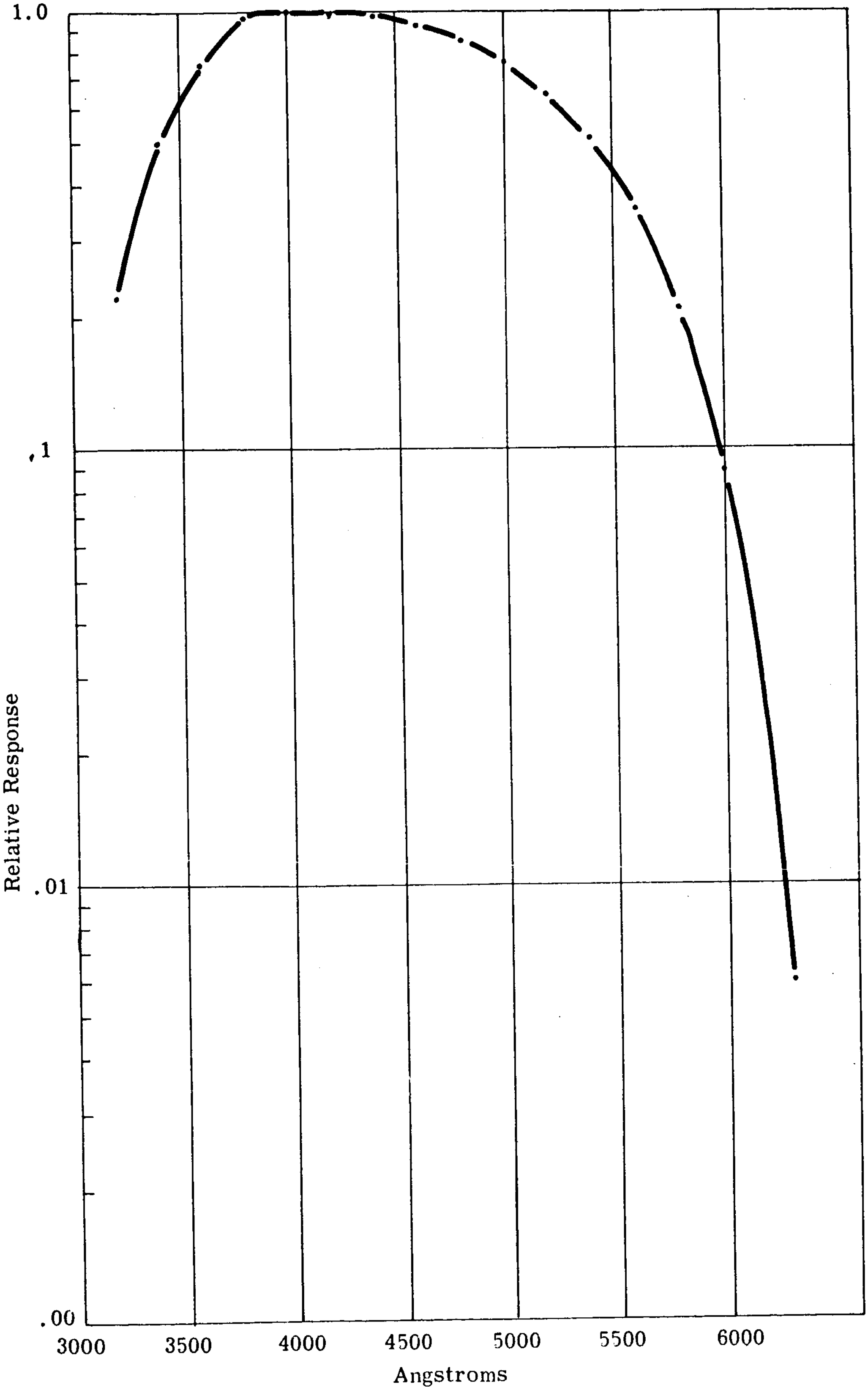


Figure 8 SPECTRAL CHARACTERISTIC PSST P/M TUBE FLIGHT UNIT

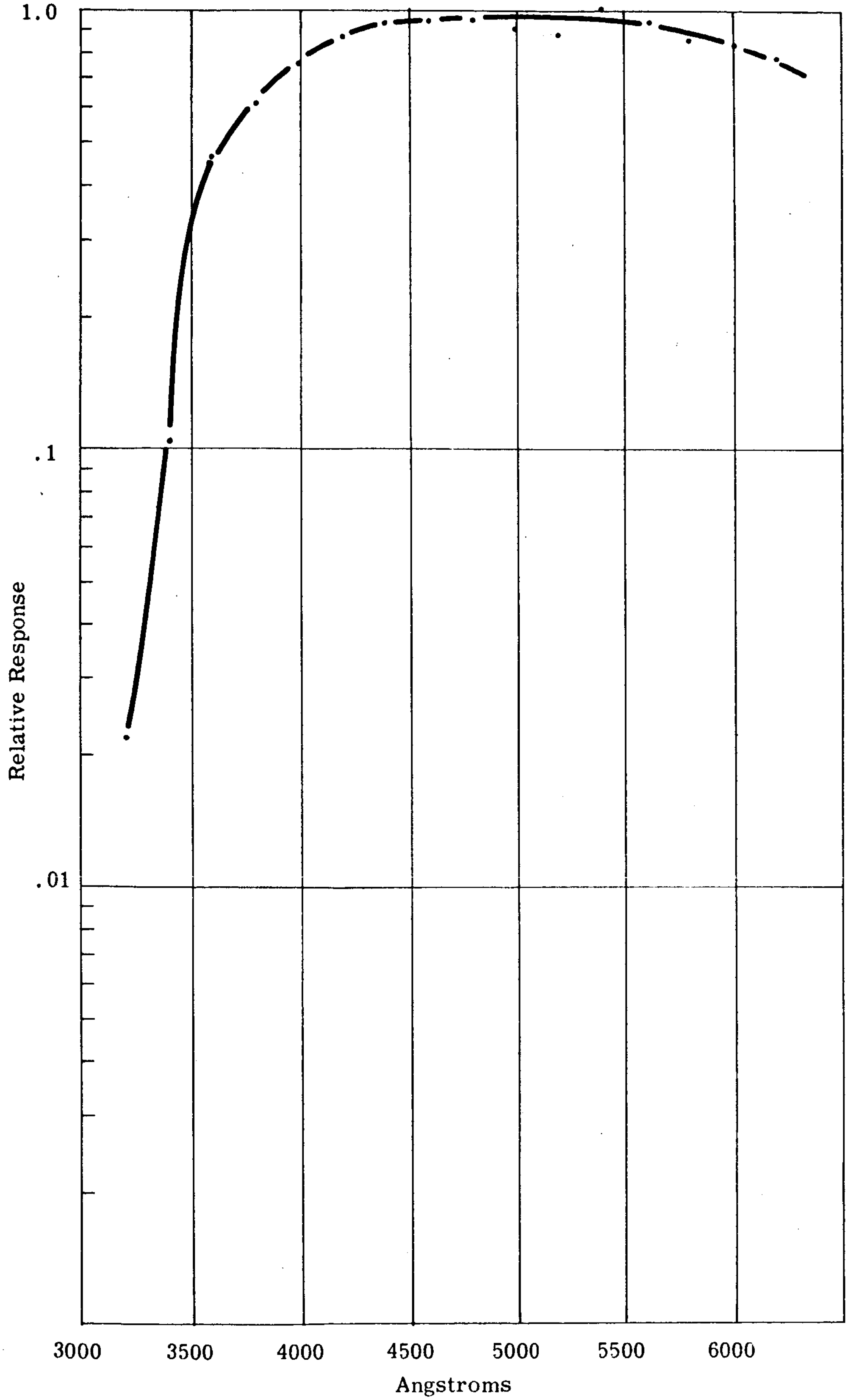


Figure 9 SPECTRAL CHARACTERISTIC PSST OPTICS FLIGHT UNIT

APPENDIX C

QUALITY TEST DATA, SPARE PARTS UNIT

APPENDIX C

Quality Test Data, Spare Parts Unit

The spare parts unit consists of a spare P/M subassembly only; therefore, only certain tests of Appendix A were run. These included pre, inter and post environmental frequency response tests; environmental tests consisting of acceleration shock, vibration, temperature soak, and operating temperature; and, P/M spectral response. This unit was calibrated from the flight unit. After the proper load resistor was inserted in the flight unit, it was placed in front of a chopped standard source at a set distance. The output was recorded on a Visicorder. The spare unit was then placed in the same position and the process repeated. The average pulse heights of 25 measurements was calculated and a 258K load resistor was inserted in the spare unit.

HONEYWELL

AERONAUTICAL DIVISION
BOSTON 35, MASS.

QUALITY
TEST REPORT

REPORT # 1042

DATE May 6, 1964

J R Russell/tbh

TESTED BY:

A H Myers

APPROVED BY:

DEVICE: PSST Spare Parts (P/M Subassembly)

QC # M-030 Serial Series

As indicated by accompanying test data, subject device was tested in accordance with ITI 226 and found to be:

[X] Within required tolerances

[ ] Not within required tolerances, as noted under COMMENTS, below

TEST DATA:

Spec Par	Test	Requirement	Test Result
5.1	Pre-Environmental Frequency Response		
	4.5cps-4.5KC	$\pm$ 1/4 db	See Figure 1
	25cps and 6KC	1 $\pm$ 1/4 db	
	$<$ 25 cps	6 db/oct roll-off	
	$>$ 6KC	18 db/oct roll-off	
6.0	Inter-Environmental Tests		
	Post Acceleration Post Shock Post Vibration Post 20°F Soak Post 120°F Soak	$\pm$ 1/4 db from Pre-Environmental test level	See Figure 2
	100°F Operating		See Figure 3
7.0	Post Environmental Frequency Response		See Figure 4
7.2	Spectral Response	Relative Response $\pm$ 10%	See Figure 5

COMMENTS:

Signed H R Fitzkow 5/6/64

QC FORM 1261-1

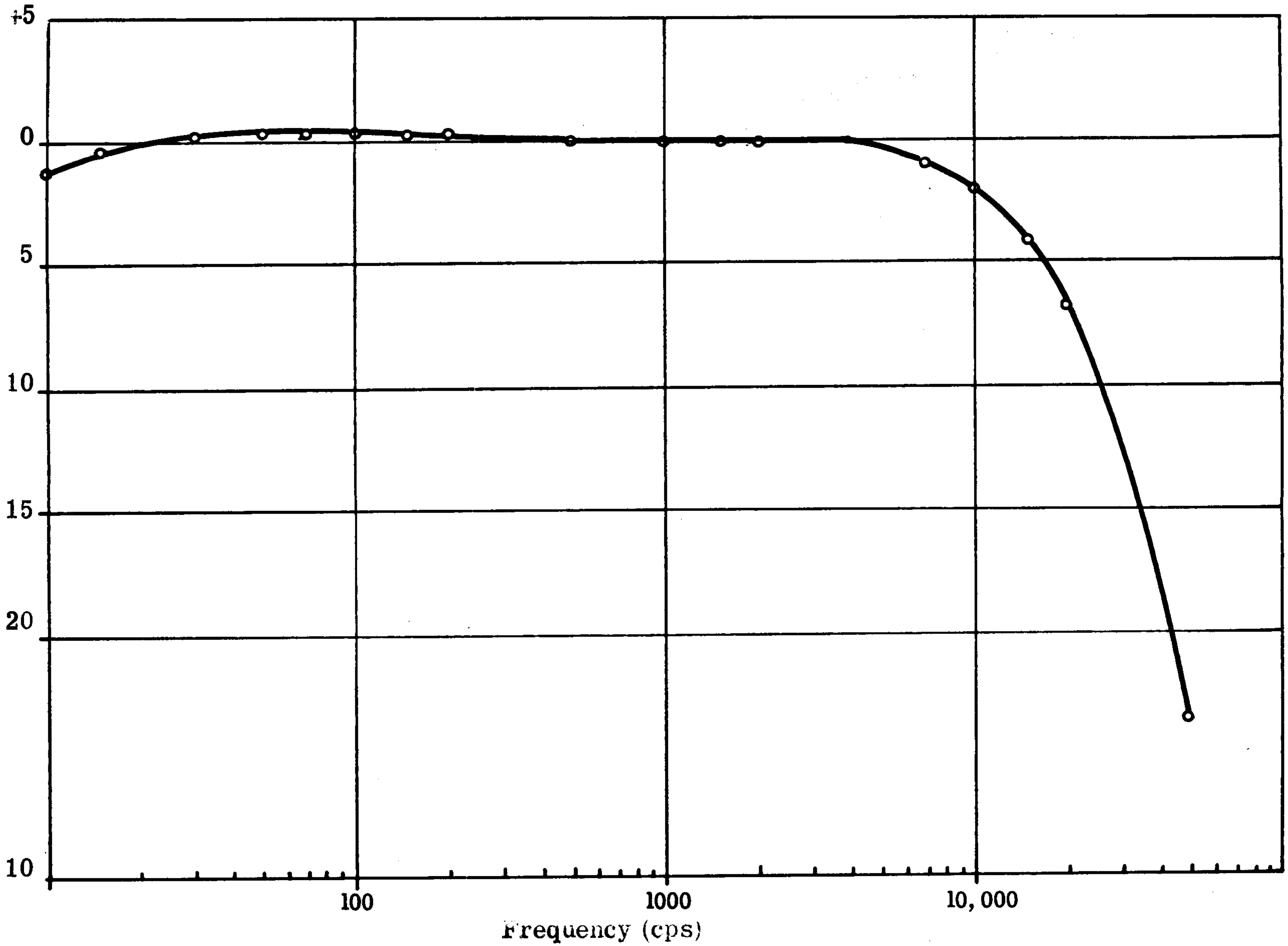


Figure 1 PSST SPARE PARTS PRE-ENVIRONMENTAL FREQUENCY RESPONSE

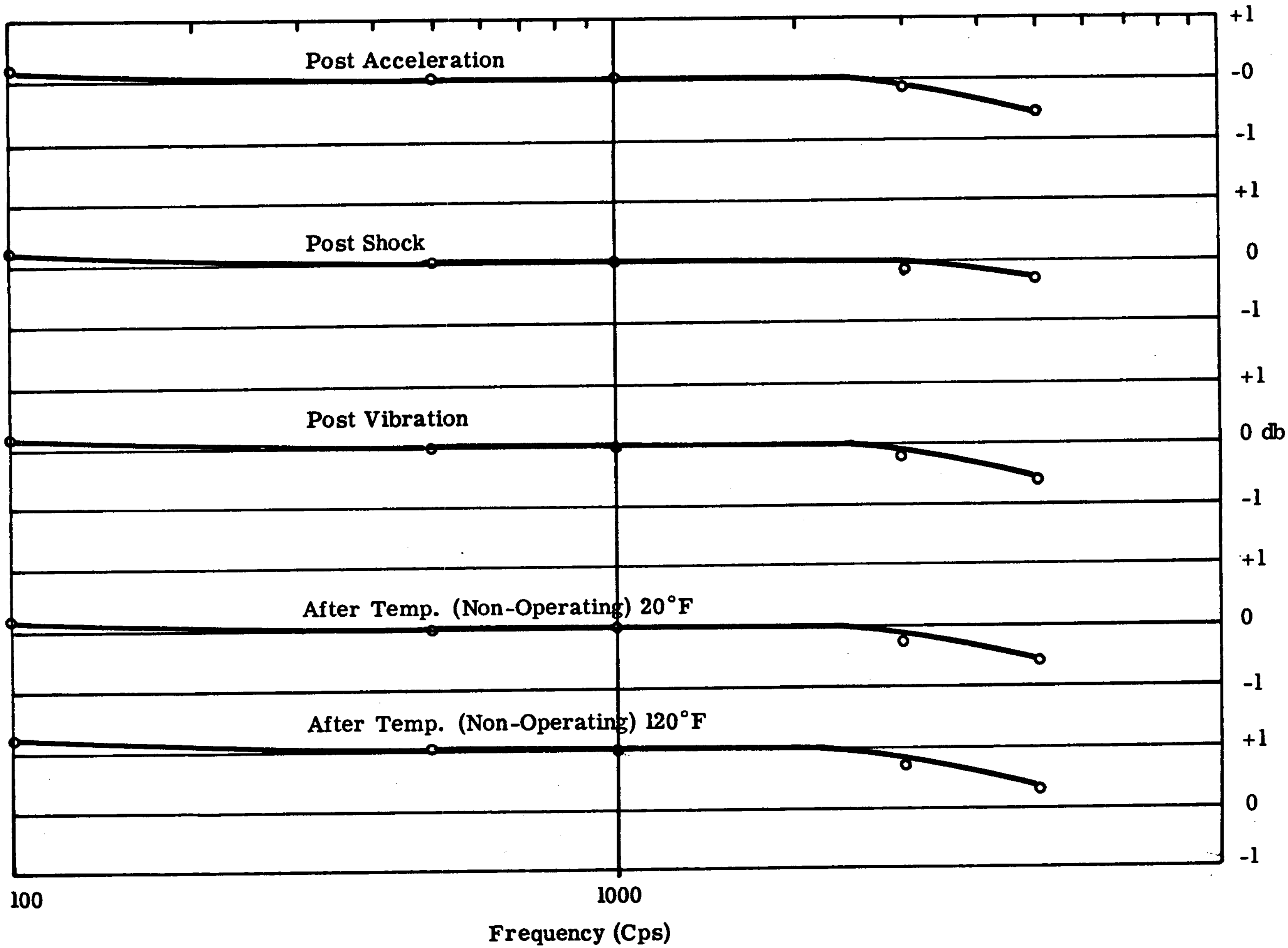


Figure 2 POST ENVIRONMENTAL FREQUENCY RESPONSE TESTS

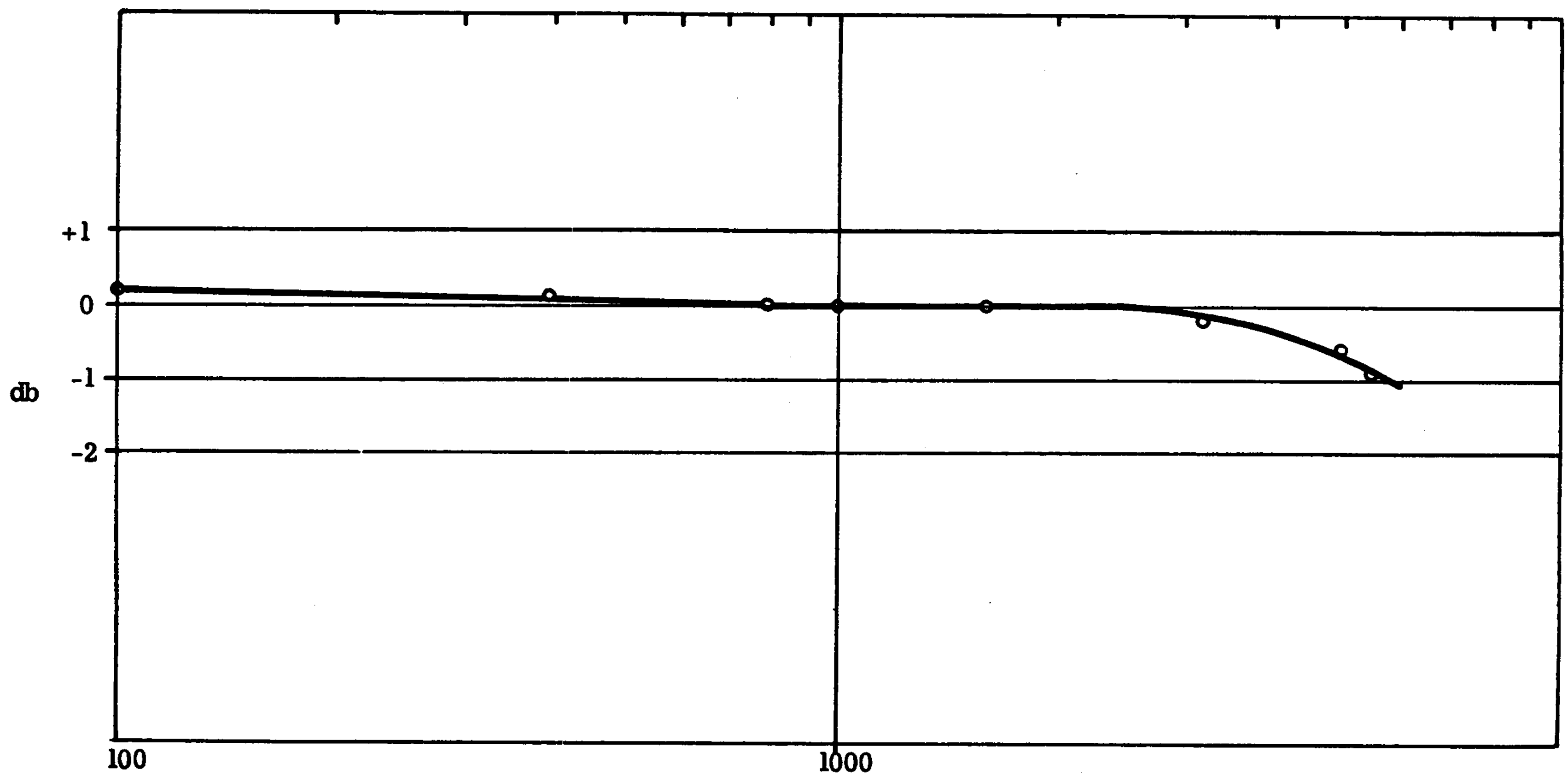


Figure 3 PSST SPARE PARTS FREQUENCY RESPONSE AT 100°F

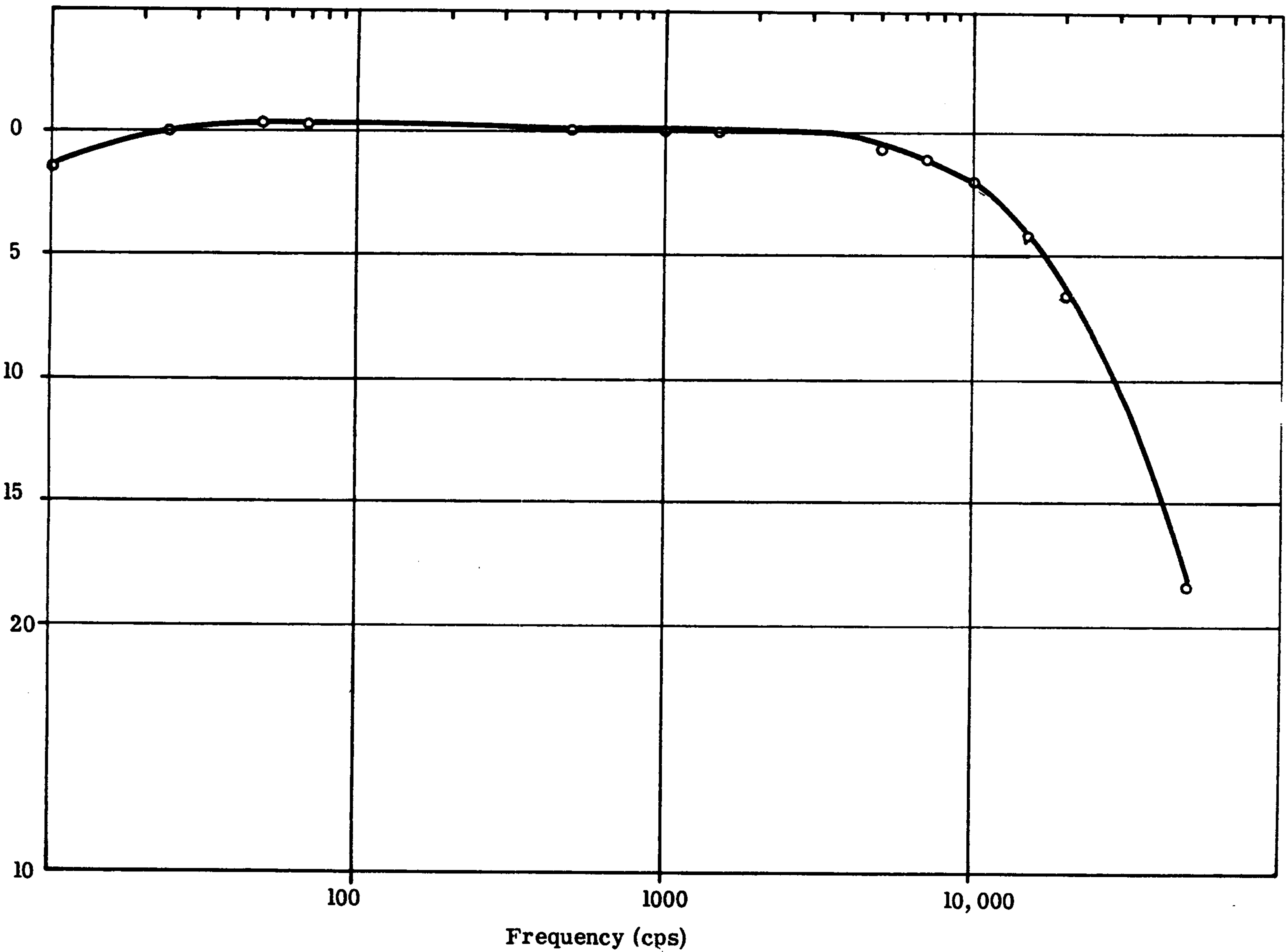


Figure 4. PSST SPARE PARTS POST ENVIRONMENTAL FREQUENCY RESPONSE

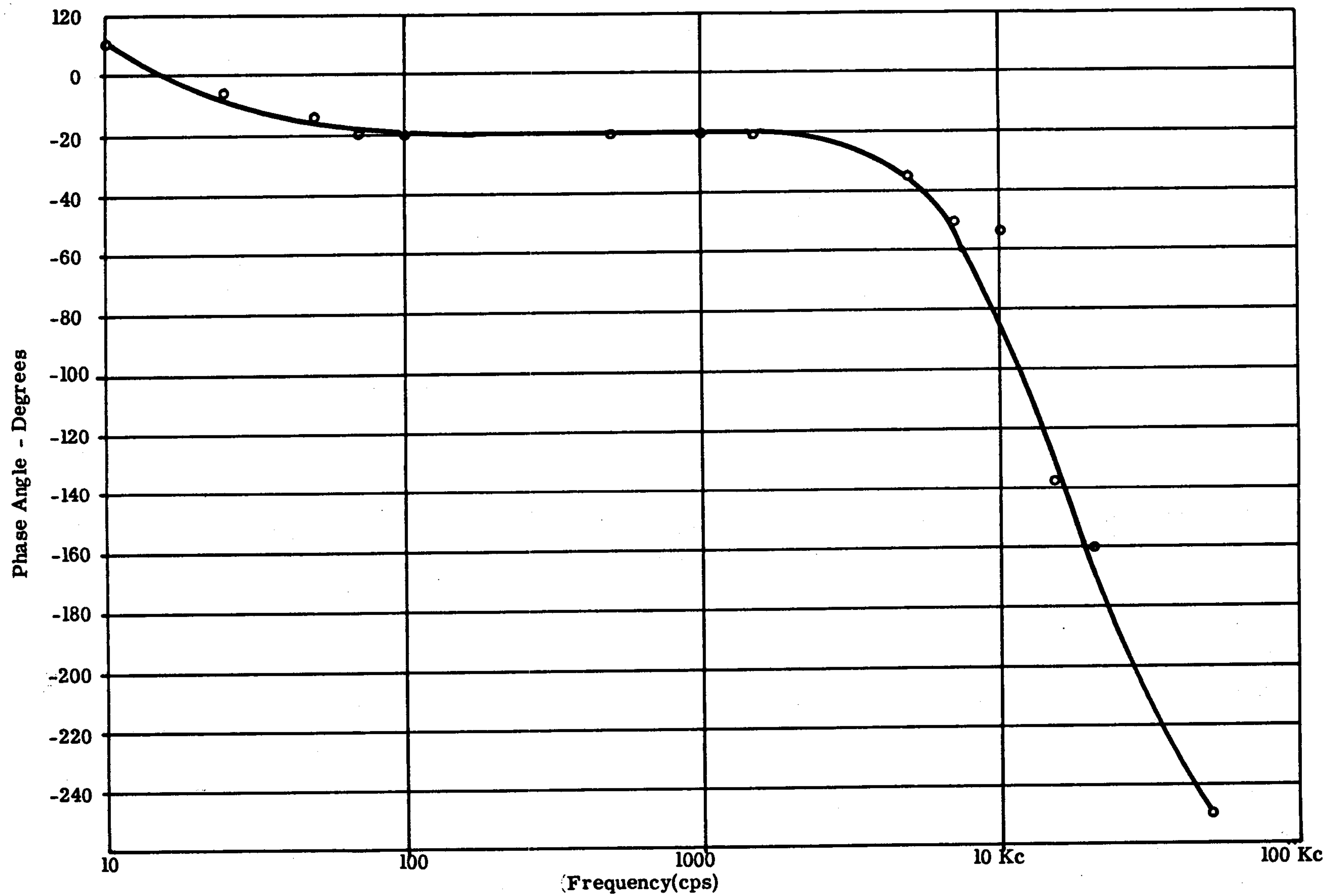


Figure 5 PHASE ANGLE VS. FREQUENCY PSST SPARE ELECTRONICS

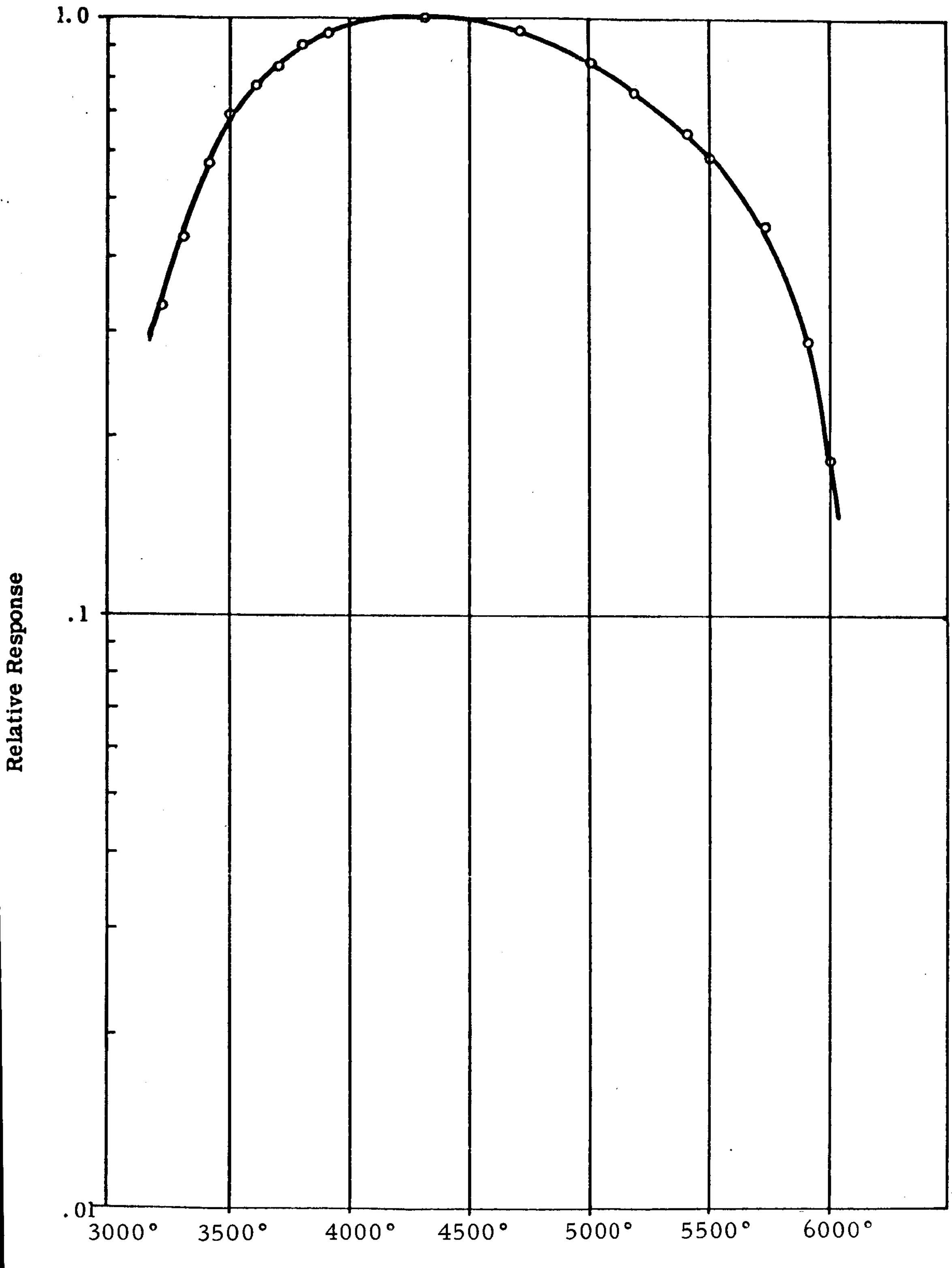


Figure 6 PSST SPARE PARTS RELATIVE SPECTRAL RESPONSE

APPENDIX D

INSPECTION AND ACCEPTANCE TEST PROCEDURES

APPENDIX D

INSPECTION AND ACCEPTANCE TEST PROCEDURES

Appendix D is the rewritten acceptance test procedure for the reworked PSST P/M subassemblies. The procedure differs from that in Appendix A in that certain tests on the optical-mechanical assembly, such as field of view, blue circle size, etc, were not repeated. The P/M subassemblies have new tubes and amplifiers, and all tests associated with these components were rerun.

SECTION 354

DATE 3-15-65
QE: w c webb
ENG: J. M. Dillard
GOVT:

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV -- See Page 1A

1 PRIOR INSPECTION COMPLETE

Assembly P/M Sub Assembly — 2 VISUAL AND MECHANICAL INSPECTION

3 CIRCUITRY

4 PRE-ENVIRONMENTAL TESTS

4.1 Telem Amp Pulse Response
4.2 Telem Amp Residual Output
4.3 P/M Assembly Frequency Response
4.4 P/M Assembly Output Level

5 ENVIRONMENTAL

5.1 Vibration
5.2 Post Vibration Check
5.3 Shock
5.4 Post Shock

6 R.F.I.

7 CALIBRATION

7.1 With Flight Optics
7.2 With Quality Optics

Installation of Final Resistors — 8 IN-PROCESS INSPECTION

9 OPERATING TEMP

9.1 P/M Assembly Tube On
9.2 Telem Assembly Tube Off

10 ALTITUDE

11 BORE SIGHT, OPTICS

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV

Final Assembly Nitrogen Fill — 12 — IN-PROCESS INSPECTION

Ship

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV

GENERAL

A. Scope

This ITI describes the inspection and test requirements for the DLG160A2 Passively Scanned Star Telescope.

B. QC Identification and Records

Initiate Fabrication and Inspection Order (FIO) for each unit, with unique QC number identifying the device. Identify the complete Quality history file for this unit with the FIO QC number.

C. Inspection/Test Acceptance Evidence

1. Upon satisfactory completion of all the inspection/test items that pertain to a given operation, indicate acceptance by signing off or stamping the appropriate box on the QC card.

2. If the inspection or test discloses one or more discrepancies, withhold the acceptance stamp or signature until satisfactory correction or disposition has been obtained, per paragraph D.

D. Inspection and Test Discrepancies

List al discrepanices encountered on an Inspection Discrepancy Notice and route to QE for material review processing. The IDN number consists of the end-item QC# followed by a sequence dash number for each successive IDN issued for that particular device. Register the IDN dash number on the FIO in the space provided: until this entry on the card is followed by acceptance stamp it indicates the WITHHELD status of the device; unless otherwise directed by the cognizant Quality Engineer, also attach a properly filled out WITHHOLD tag to the unit and retain the device in the bonded MRB area pending authorized disposition as indicated on completely signed-off come-back copy of the IDN.

E. Reference Documents

ENGINEERING	CUSTOMER
Assy. Drawing DLG160A2 ES 25440-ES02	NASA Langley Spec L3300

INSPECTION AND TEST OPERATIONS

1. PRIOR INSPECTIONS COMPLETE

Verify that DLG160A2 sub-assembly inspection and test operations have been satisfactorily completed and evidenced in accordance with applicable ITI's. Inspect Optics for visual damage during storage.

2. VISUAL AND MECHANCIAL Before Testing

Visually inspect unit for workmanship, cleanliness, appearance, etc. Check alignment of assembled unit.

3. CIRCUITRY

Check identification of leads per print.

4. PRE-ENVIRONMENTAL TESTS

All tests of an optical or electrical nature are to be at 72 $\pm$ 2°F unless otherwise stated.

4.1 Telemetry Amplifier Pulse Response

4.1.1 Connect a 2K resistor and 100K resistor to the terminals provided in junction box in P/M assembly to simulate final calibration resistors. Connect 28 volt power to amplifiers only.

Apply a 300 m sec square pulse of current through this 100K resistance string and vary this current pulse in magnitude from 0 to 100μa peak. Output of telemetry amplifier should be loaded with 350K resistor for all tests.

4.1.2 At inputs of 1, 2, 5, 10, 50, 100μa, record the output wave shape peak heights.

For 10μa and 50μa equivalent inputs, record the exact wave shape noting the rise time and the fall time of the pulse.

The decay time constant for the falling edge determines the low end 3 db point and should be below 10 cps. The rise time constant for the leading edge determines the high end 3 db point and should be between 1K and 2K cps.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV

4.2 Telemetry Amplifier Residual Output

With no signal input measure the output voltage with a D.C. VTVM. The output shall be below .3 volts.

4.3 P/M Assembly Frequency Response

4.3.1 Use a light diode of known frequency performance and an oscillator to drive the network of variable frequency. Place P/M Assembly in close proximity to the diode in a dark chamber and supply 28 volts to P/M assembly. Place a 50K resistor in parallel with 200$\mu\mu$f across output of signal amplifier. Connect 28 volts to complete system.

4.3.2 Drive the light diode for an output from the signal amplifier of 4 volts peak to peak at 1000 cps. Observe outputs on a scope and HP 302 wave analyser.

Vary the frequency and record and plot output, and check for response per the following table at frequency settings of 0.1, 1, 2, 5, 10, 15, 25, 50, 100, 500 cps and 1, 3, 6, 10, 20, 30, 50KC. Take measurements at all above listed points.

Freq.	DB	Tol
0.1 1 cps		No inflections
1	-35	± 4
2	-22	± 3.5
3	-15	± 3
4	-12	± 2.5
5	-10	± 2
25	-1	± 1/4
50 3 KC	Flat	± 1/4
6000	-1	+ 1/2, -1/4
10 KC	-3	± 1
20 KC	-11	± 2
30 KC	-13	± 3
50KC	-32	± 4

4.4 P/M Sub-Assembly Output

Adjust diode drive for a 4 volt peak to peak signal and record precise electrical and physical test conditions so that system check can be faithfully reproduced. This includes diode to P/M distance and position, and diode drive voltage.

5.0 ENVIRONMENTAL

5.1 Vibration

5.1.1 X Axis

Mount the unit in the vibration apparatus using the designated fixture. Perform vibration according to the following table:

Frequency Range (cps)	Sweep Speed Oct/Min	Time Duration Seconds	Acceleration "G" (0 to peak)
20-2000	4.0	---	1.0
20-200	4.0	---	2.5
200-500	4.0	---	6.5
500-2000	4.0	---	11.5
550-650	Log Sweep	18 Sec.	40.0

5.1.2 Y Axis

Remount the unit and use the following table:

Frequency Range (cps)	Sweep Speed Oct/Min	Time Duration Seconds	Acceleration "G" (0 to peak)
20-2000	4.0	---	1.0
20-200	4.0	---	1.25
200-500	4.0	---	3.25
500-2000	4.0	---	5.50
550-650	Log Sweep	18 Sec.	10.00

5.1.3 Z Axis

Repeat 5.1.2 for this axis.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV

5.2 Post Vibration Check

5.2.1 Remount P/M assembly in dark chamber in exact test conditions as 4.3, 4.4 and duplicate tests of 4.3 and 4.4 noting any deviation from previous data.

5.3 Shock

5.3.1 Mount the unit in the shock apparatus such that the unit will have a 50 "G" shock imposed along the X axis. Use a "memory-scope" to monitor the shock load. The shock shall be an approximate half sine wave pulse of 5 to 15 milliseconds duration.

Take picture of memoscope wave shape for the actual run.

5.4 Post Shock Test

5.4.1 Repeat 5.2.1.

6.0 R.F.I.

6.1 Take the flight P/M sub-assembly to an R.F.I. test facility. With the P/M tube masked to prevent light damage, subject it to an R.F.I. Test per paragraph 4.3.4.1, 4.3.4.2 of MIL-I-6181D except that frequency ranges are changed to read in 4.3.4.1 -- frequency range 150 to 7000 mc -- and in 4.3.4.2 the table shall read:

Frequency	Open-Circuit Microvolts	Antenna
0.15 to 25 mc	100,000	41 inch rod
25 to 35 mc	100,000	35 mc dipole
35 to 400 mc	100,000	tuned dipole
4K to 7K mc	100,000	same as used for radiation test (4.3.2)

6.2 Perform all tests while the unit is energized. Monitor dark current of the P/M tube checking for conducted noise. Using an oscilliscope and a voltmeter monitor the output for an increase in output noise. ~~Any increase greater than 5 db is cause for rejection.~~ The noise voltages of the amplifier shall be below 25 mv for all RFI radiated tests and for conducted audio tests between 500-2000 cps. Test data will be recorded for the entire conducted audio frequency range.

7. CALIBRATION

7.1 This calibration will be performed on a calibrated Star simulator, property of NASA, located at Baird Atomic. This will be conducted in a way that will make it possible to correlate the 2 P/M sub-assemblies. The collimated beam of energy will be chopped at 600 cps and will be capable of simulating 3 color temperatures at 4 magnitude levels.

7.1.1 Mount the flight P/M assembly on the flight optics with a 100K anode load resistor in circuit. Set Star Simulator for an AO-O Magnitude Star and measure the output of the signal amplifier. Mathematically determine the resistor that would produce a 5 V peak output and place a resistor as close to this value as possible in place of the 100K before continuing. (This Value is the sum of the resistors that drive the telemeters and signal amplifiers.)

7.1.2 With proper load resistor in place, measure the output with the tabulated star magnitudes and colors to determine the response of the PSST.

Color	AO	GO	MO
Mag	0	0	0
	1	1	1
	2	2	2
	3	3	3

Alternate magnitude may be used to produce adequate curve.

7.1.3 Use the spectral transmission curve previously established for the PSST optics and the spectral characteristics of the P/M tube and compute and plot the PSST system relative spectral response.

7.2 Mount the flight P/M sub-assembly with same load resistor on the qualification unit optics.

Use the same star conditions as in 7.1.2 and record the peak outputs of the signal amplifier for each star combination. This will provide a calibration of the qual. optics in terms of the flight optics so that the second P/M sub-assembly may be calibrated to match the flight unit at a later date.

8. Check the selection and installation of the resistors R1, R2 that drive the telemetry and signal amplifiers.

9. OPERATING TEMPERATURE CHECK

9.1 P/M Sub-assembly Check

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV

9.1.1 Place unit in a dark temperature chamber at 100°F in a duplicate of test conditions of 4.3 and allow 1/2 hour for stabilization.

Vary the frequency and plot outputs as specified in 4.3.

9.1.2 Return temperature to room temperature and stabilize for 15 minutes. Repeat test measurements of 9.1.1. The gain should be stable within 10%.

9.2 Telemetry Amplifier Operating Temperature Test

9.2.1 Turn off 28 volts to H v supply and connect the test circuit of 4.1.1 to the anode of deenergized P/M tube to simulate tube currents.

9.2.2 Using temperatures of 72 ± 2°F, 85 ± 2°F, 100 ± 2°F, repeat the tests of 4.1 except using the new computed resistor values.

10. ALTITUDE

This test is to check for any Hi voltage breakdown as pressure is decreased.

10.1 Place P/M sub-assembly with P/M tube covered in a vacuum chamber. Provide 28 volts to system and connect a scope and/or VTVM across signal amplifier output.

10.2 Reduce pressure to 0.1 MM Hg and observe output for any abnormal pulses or noise that would indicate arc-over.

11. BORE SIGHTING

11.1 Place a 90° plane parallel mirror and a Taylor-Hobson alignment telescope on a surface plate. Adjust the level of the telescope so that its image is centered and remains centered as mirror is reversed. This establishes telescope parallelism with plate. Place the PSST with sun shield facing telescope. Line up the reticle to the cross lines of the Taylor-Hobson. Measure any vertical deviation. The vertical alignment should be within 36 arc seconds.

11.2 Check azimuth deviation of Optics by using special mounting plate and checking deviation of optic axis from plane parallel placed in front of mounting plate. This should reproduce initial value of 7' 16' ± 20". Draw diagram showing relation of optical and mechanical axis.

INSPECTION & TEST INSTRUCTIONS

SUBJECT: DLG160A2 Passively Scanned Star Telescope

REV

12. NITROGEN FILL

Check on performance of flushing and filling operation of flight unit with dry nitrogen gas. Check capping of fill terminal.

APPENDIX E

QUALITY TEST DATA - FLIGHT P/M SUBASSEMBLY

The test data in this appendix are the results of the tests on the flight unit which were run in accordance with the procedures given in Appendix D.

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1156
DATE 4-23-65
TESTED BY:
APPROVED BY:

DEVICE: DLG160A2 PASSIVELY SCANNED STAR TELESCOPE

QC # 3504 Serial 1 Series K2

As indicated by accompanying test data, subject device was tested in accordance with ITI 354 Rev. A and found to be:

[X] Within required tolerances
[ ] Not within required tolerances, as noted under COMMENTS, below

TEST DATA:

Spec Par	Test	Requirement		Test Result
4.0	Pre-environmental			
4.1	Telem Amp Pulse Response			
		Low 3 db point < 10 cps or Fall Time > 25 ms		27 ms
		High 3 db point 1K to 2K or Rise Time 125 to 250 usec.		220 usec
4.3	P/M Assembly Freq Response			
		2 cps	$-22 \pm 3\frac{1}{2}$	
		3 cps	-15 ± 3	
		4 cps	$-12 \pm 2\frac{1}{2}$	
		5 cps	-10 ± 2	
		25 cps	$-1 \pm \frac{1}{4}$	Figure 1
		50 cps to 3 KC	$0 \pm \frac{1}{4}$	
		6 KC	-1	
		10 KC	-3 ± 1	
		20 KC	-11 ± 2	
		30 KC	-18 ± 3	
		50 KC	-32 ± 4	

COMMENTS:

Signed ________ __/__/__

QC FORM 1261-1

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1156
DATE 4-23-65
PAGE 2 OF

DEVICE: DLG160A2 PASSIVELY SCANNED STAR TELESCOPE

QC # 3504 Serial 1 Series K2

TEST DATA: CONTINUED:

Spec Par	Test	Requirement	Test Result
5.4	Post-environmental		
5.4.1	Telem Pulse Response		
		Same as 4.1 Low	25 ms
		High	230 usec
	P/M Assembly Freq Response		
		Same as 4.3	Figure 2
6.0	RFI Susceptability		See attached report
7.0	Calibration		
	Initial - 5V output for AO-0 Star Computed Resistance		273K
	Corrected output curve for A, G, M Simulated Stars		See Figure 7.3
SUPPLEMENTAL TEST			
	Post Calibration Frequency Response		
	These curves were made to compare amplifier and P/M sub-assembly frequency response under several conditions		Figure 4
		P/M Assembly 100K load with extra lead	Curve 1
		Without extra lead	Curve 2
		Assembly 270K load without extra lead	Curve 3

COMMENTS:

Signed ________ __/__/__

QC FORM 1261-1

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1156
DATE 4-23-65
PAGE 3 OF

DEVICE: DLG160A2 PASSIVELY SCANNED STAR TELESCOPE

QC # 3504 Serial 1 Series K2

TEST DATA: CONTINUED:

Spec Par	Test	Requirement	Test Result
SUPPLEMENTAL TEST CONTINUED		Amplifier only 270K load	Curve 4
9.0	Operating Temp Check		
9.1	P/M Sub-assembly Freq Response	100°F	
		Same as 4.3	Figure 5
	Freq Response 80°F		
		Same as 4.3	Figure 5
9.2	Telem Amp Pulse Response		
	Temp 72°F	72°F	
	50 ua pulse	Fall Time > 25 ms Rise Time 125 < x < 250 usec	25 ms 200 usec
	Temp 85°F		
	50 ua pulse	Fall Time Same Rise Time	25 ms 210 usec
	Temp 100°F		
	50 ua pulse	Fall Time Same Rise Time	25 ms 210 usec
	Telem Amp Gain Linearity		Figure 6
	Temp 72°F 85°F 100°F		Curve 1 Curve 2 Curve 3

COMMENTS:

Signed ________________ __/__/__

QC FORM 1261-1

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1156
DATE 4-23-65
PAGE 4 OF

DEVICE: DLG160A2 PASSIVELY SCANNED STAR TELESCOPE

QC # 3504 Serial 1 Series K2

TEST DATA: CONTINUED:

Spec Par	Test	Requirement	Test Result
11.0	Bore Sight Check		
		Should duplicate previous angles	
	Vertical Alignment Error		

COMMENTS: ____________________

Signed ____________ __/__/__

QC FORM 1261-1

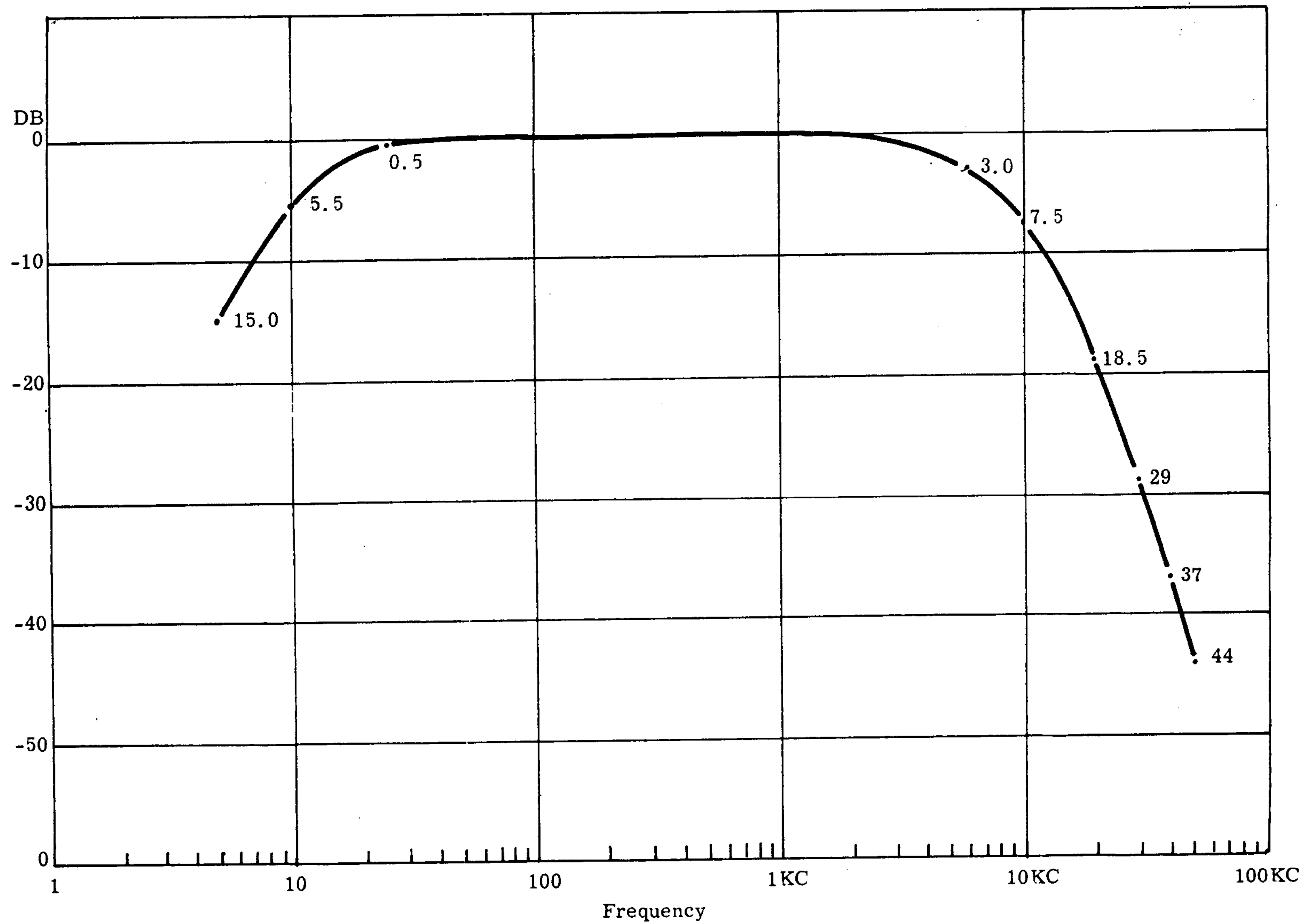


Figure 1 FLIGHT UNIT PRE-ENVIRONMENTAL P/M ASSEMBLY FREQUENCY RESPONSE 100 K LOAD

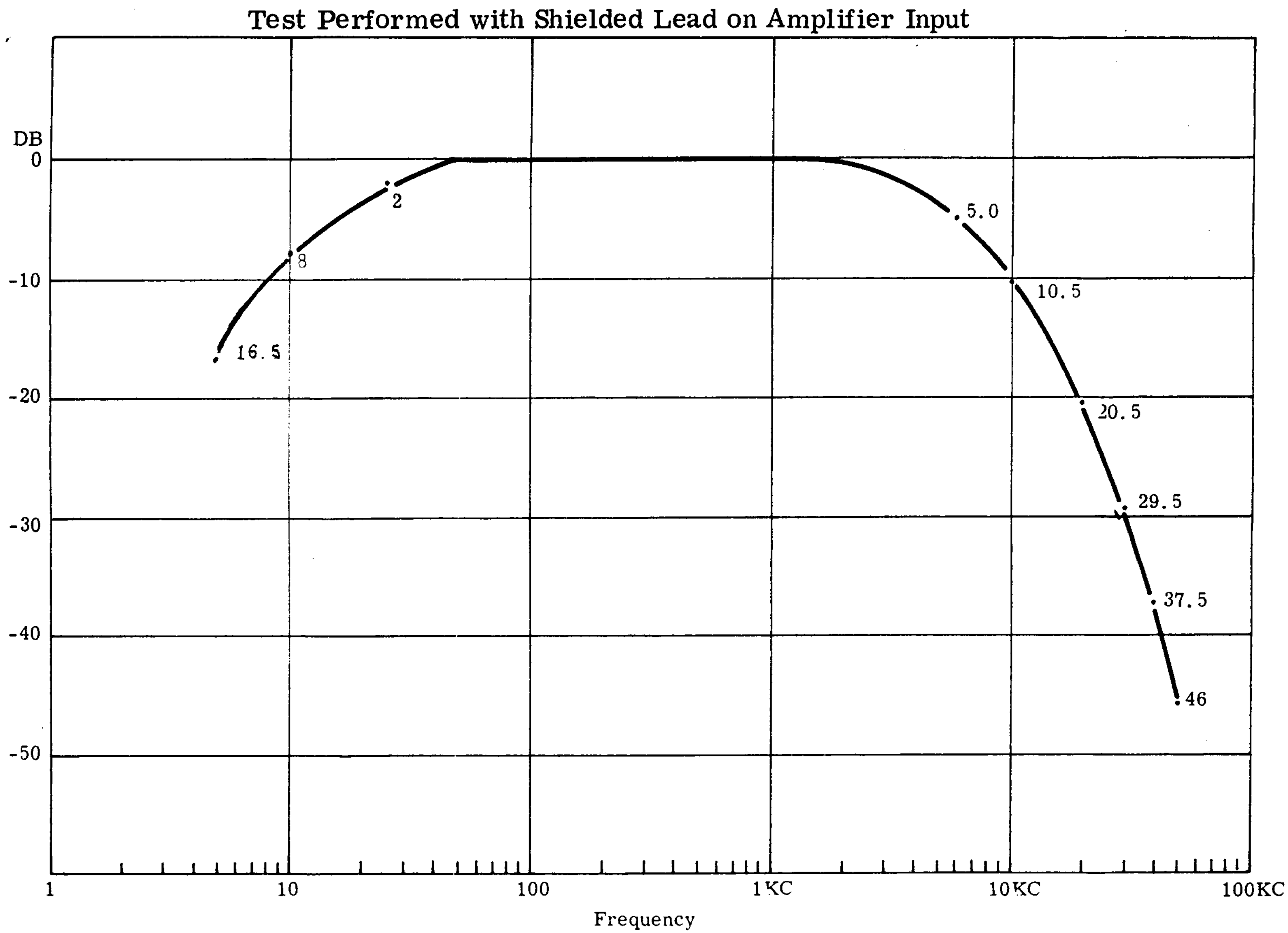


Figure 2 FLIGHT UNIT POST-ENVIRONMENTAL P/M ASSEMBLY FREQUENCY RESPONSE 100 K LOAD

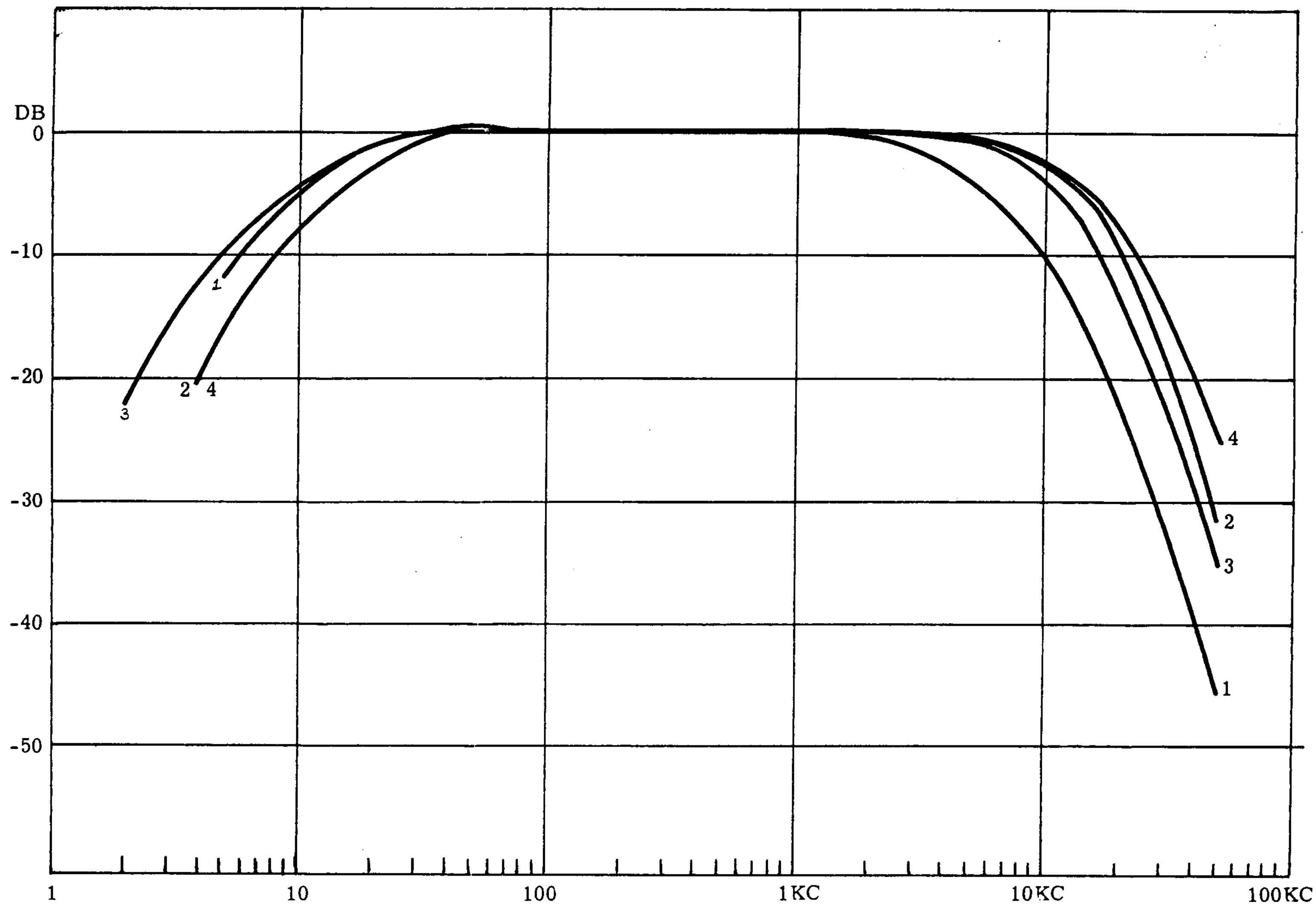


Figure 4 FLIGHT P/M SUBASSEMBLY FREQUENCY RESPONSE

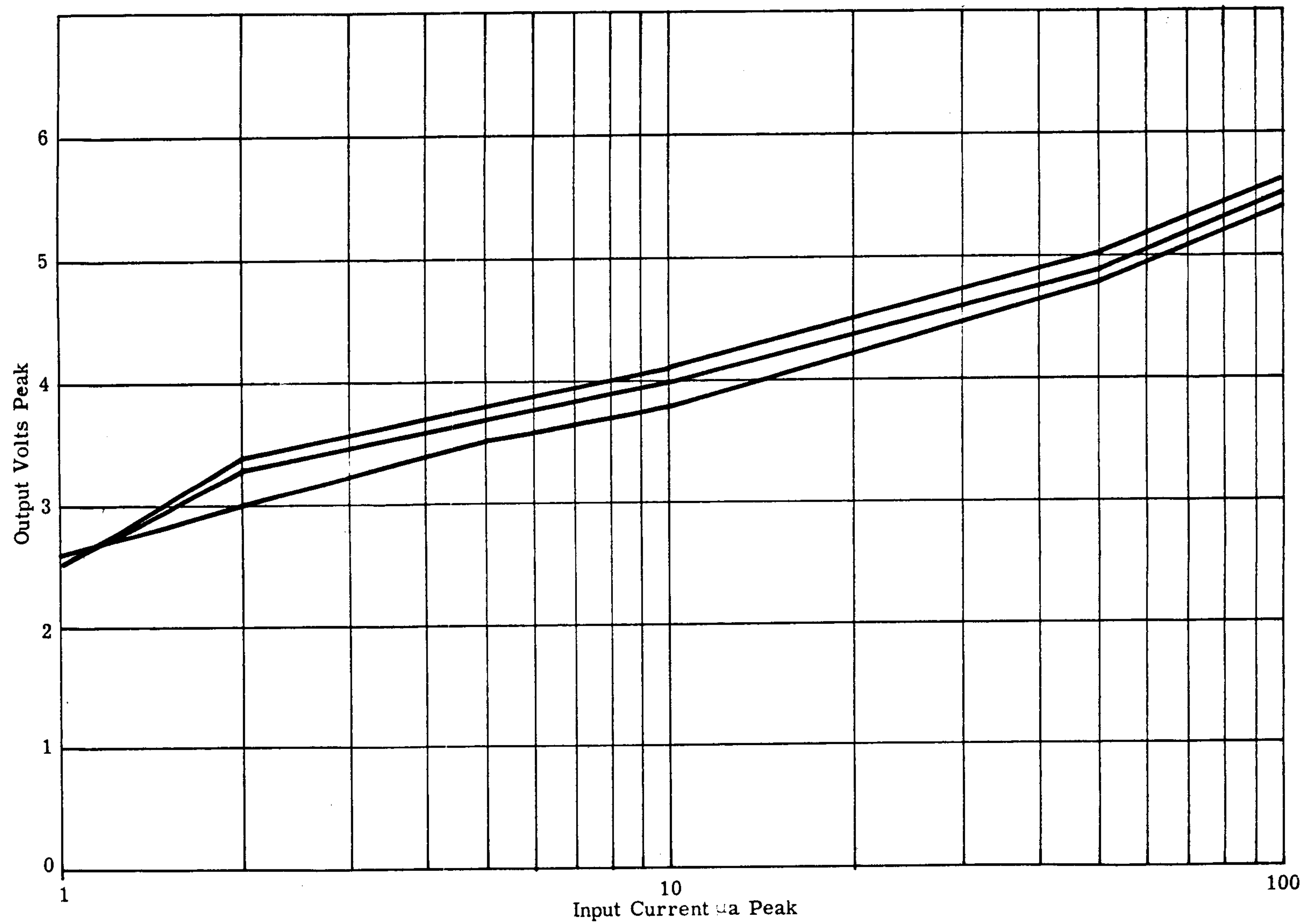


Figure 6 TELEMETRY AMPLIFIER GAIN LINEARITY VS TEMPERATURE

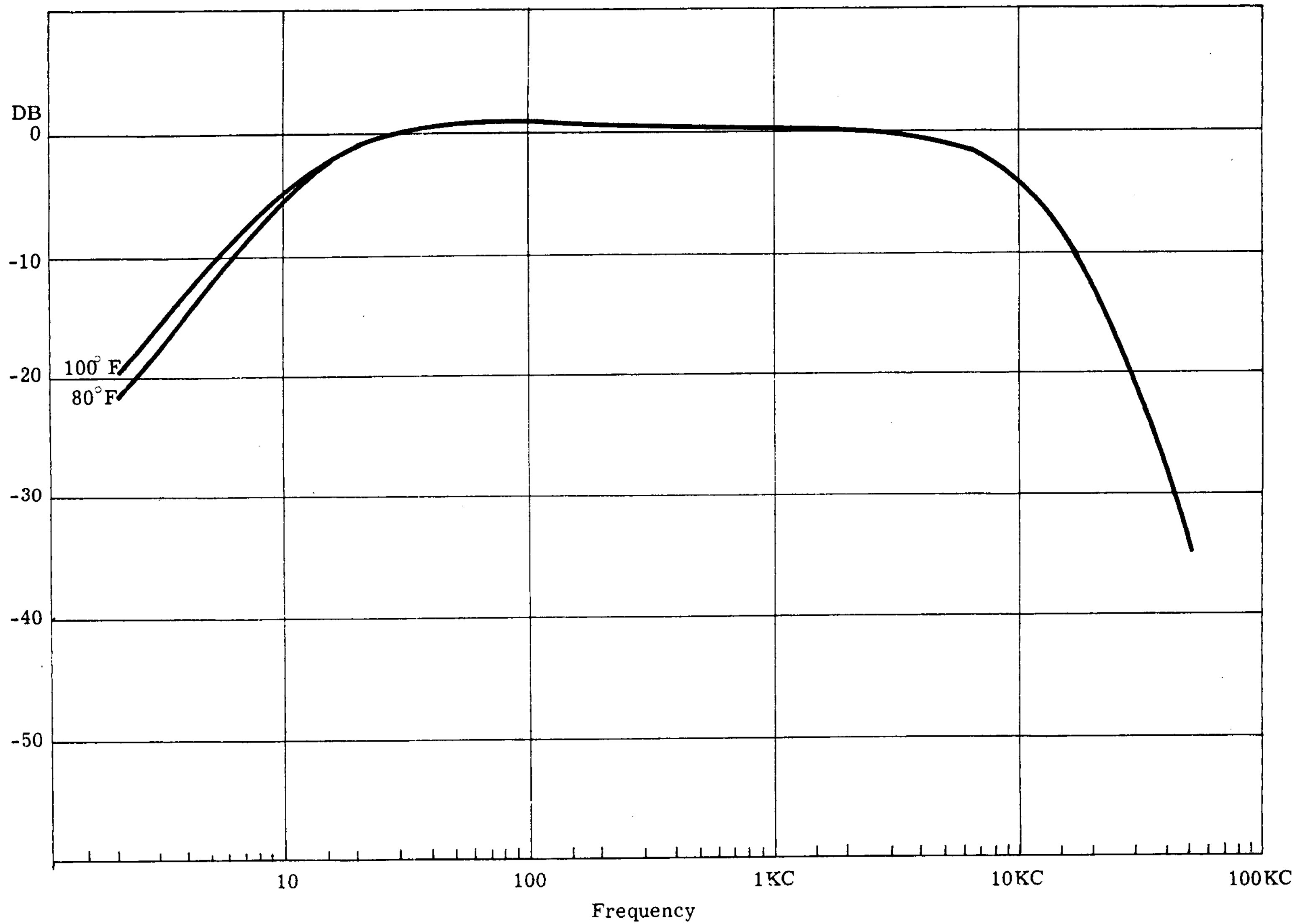


Figure 5 FLIGHT UNIT P/M ASSEMBLY OPERATING TEMPERATURE FREQUENCY RESPONSE

APPENDIX F

QUALITY TEST DATA - SPARE P/M SUBASSEMBLY

The test data in this appendix are the results of the tests of the spare unit which were run in accordance with the procedures given in Appendix D.

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1177

DATE 6-28-65

TESTED BY:

APPROVED BY:

DEVICE: DEK3A1 PSST TELEMETRY AMPLIFIER SERIES K1, S/N E-2 AND SPARE P/M ASSEMBLY FOR DLG160A2 PSST

QC # 3504 Serial Series

As indicated by accompanying test data, subject device was tested in accordance with ______________ and found to be:

- [ ] Within required tolerances
- [x] Not within required tolerances, as noted under COMMENTS, below

TEST DATA:

Spec Par	Test	Requirement	Test Result
4.0	Pre-environmental		
4.1	Telem Amp Pulse Response	Low 3db point 10 cps or Fall Time 25 ms	23 ms
		High 3db point 1K to 2K or rise time 125 to 250 u sec	200 us
4.2	Residual Output	.3V max.	.25 V
4.3	P/M Assembly Freq Response		
		2 -22 $\pm$ 3½ db	
	THESE SPECIFICATION LIMITS DO NOT APPLY IN FULL EXCEPT AT FINAL FREQUENCY RESPONSE UNDER SECTION 9.0.	3 -15 $\pm$ 3	
		4 -12 $\pm$ 2½	
		5 -10 $\pm$ 2	
		25 -1 $\pm$ ½	Figure 1
		50 cps to 3KC 0 $\pm$ ½ db	
		6KC -1 50KC -32 $\pm$ 4	
		10KC -3 $\pm$ 1	
		20KC -11 $\pm$ 2	
		30KC -18 $\pm$ 3	

COMMENTS: Telem Pulse Response low 3db point is 10.7 cps should be less than 10 cps. Same result par. 4.1, 5.4.1 and 9.2.

Signed ______________ __/__/__

QC FORM 1261-1

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1177
DATE 6-28-65
PAGE 2 OF 8

DEVICE: DEK3A1 PSST TELEMETRY AMPLIFIER SERIES K1, S/N E-2 AND SPARE P/M ASSEMBLY FOR DLG160A2 PSST

QC # 3504 Serial Series

TEST DATA: CONTINUED:

Spec Par	Test	Requirement	Test Result
5.4	Post-Environmental		
5.4.1	Telem Pulse Response	Same as 4.1	
		Low	23 ms
		High	200 us
	P/M Assembly Freq Response		
		Same as 4.3	Figure 2
6.0	RFI Susceptability	Not Applicable for Spare Part	
7.0	Calibration		Figure 3

The curves of Figure 3 are the outputs observed using the qualification optics and the star simulator at Baird Atomic. They have been reduced by 85% to adjust for the 84.5K resistance now in the circuit.

They will not match the outputs of the flight unit when mounted on the flight optics.

Spec Par	Test	Requirement	Test Result
9.0	Operating Temp Check		
9.1	P/M Sub-assembly Freq Response 100°F		
		Same as 4.3	Figure 4
	Freq Response 72°F		
		Same as 4.3	Figure 4
9.2	Telem Amp Pulse Response		
	Temp 72°F	Fall Time > 25ms Rise Time 125 < x < 250 u sec	23 ms 210 us

COMMENTS: See Comments under Par. 7.0.

Signed ______________ __/__/__

QC FORM 1261-1

Honeywell
RADIATION CENTER

QUALITY
TEST REPORT

REPORT # 1177
DATE 6-28-65

DEVICE: DEK3A1 PSST TELEMETRY AMPLIFIER SERIES, K1, S/N E-2 AND SPARE P/M ASSEMBLY FOR DLG160A2 PSST

QC # 3504 Serial Series

TEST DATA: CONTINUED:

Spec Par	Test	Requirement	Test Result
9.2 (Continued)			
	Temp 85°F	Fall Time	23 ms
		Rise Time	200 us
	Temp 100°F		
	50 ua Pulse	Fall Time	23 ms
		Rise Time	200 us
	Telem Amp Gain Linearity		Figure 5
	Temp 72°F		Curve 1
	Temp 85°F		Curve 2
	Temp 100°F		Curve 3
	Residual Output	.3V max.	.25

COMMENTS: ______

Signed ______ __/__/__

QC FORM 1261-1

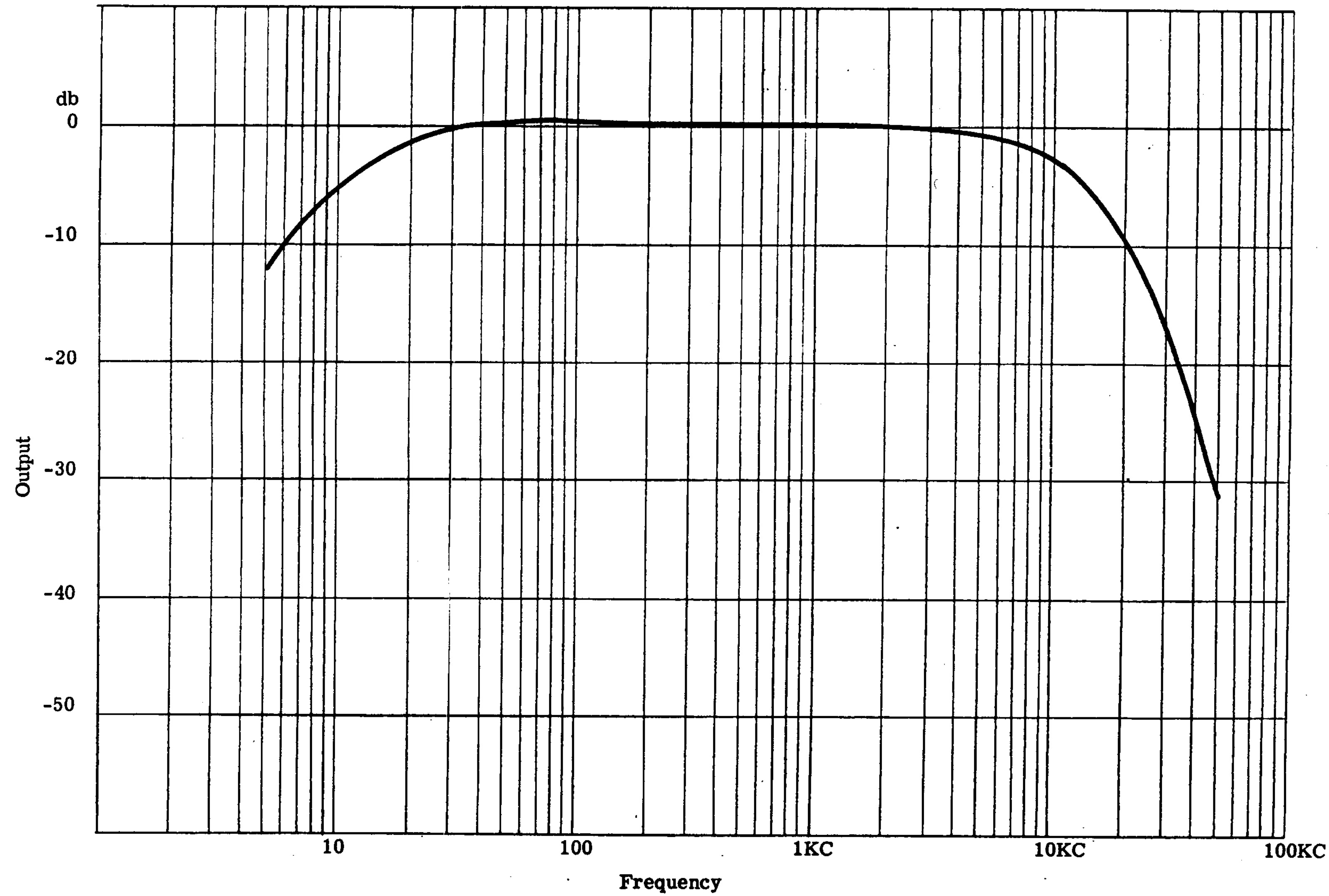


Figure 1 SPARE UNIT PRE-ENVIRONMENTAL P/M ASSEMBLY FREQUENCY RESPONSE (100 K LOAD)

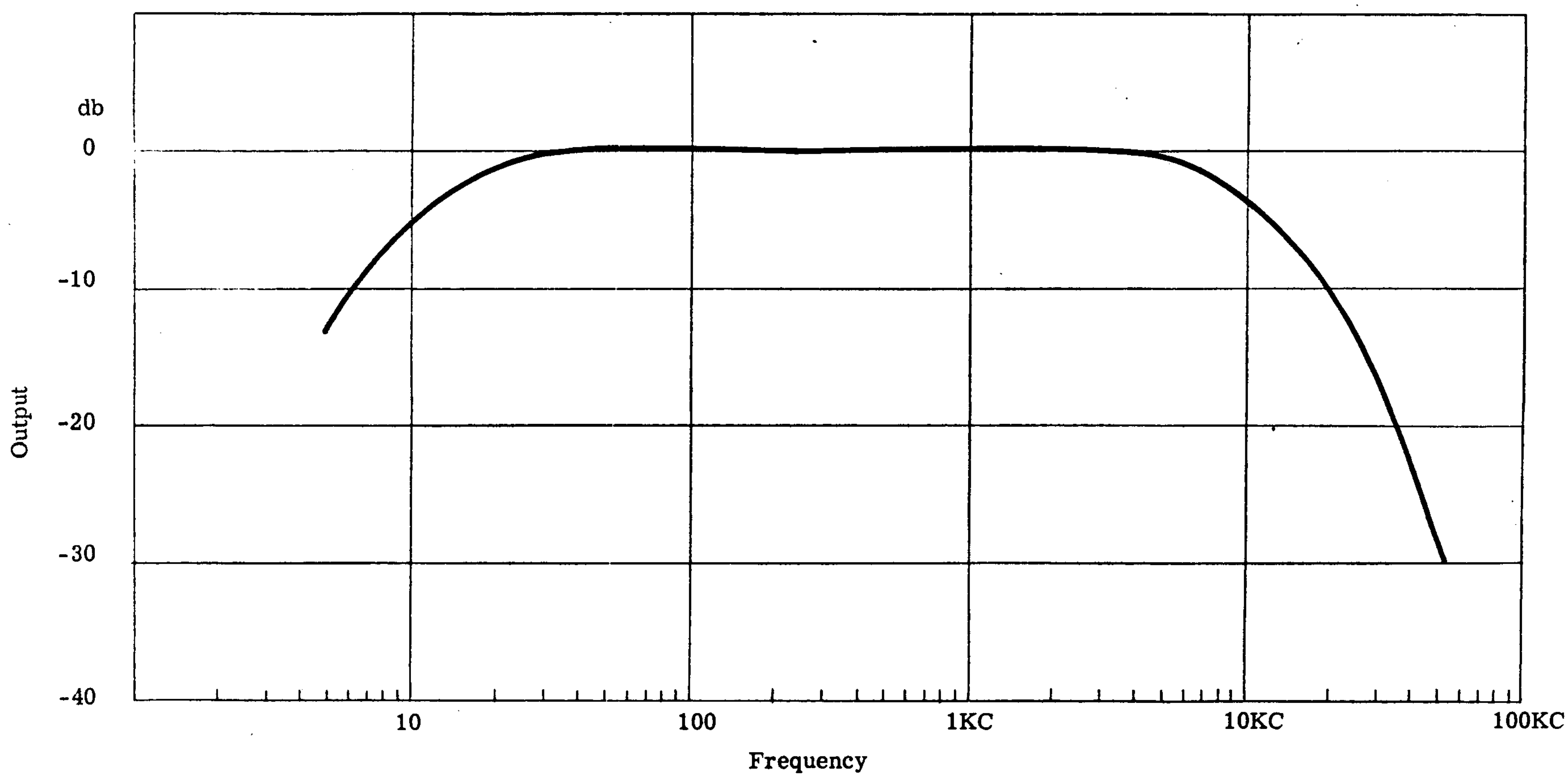


Figure 2 SPARE UNIT POST ENVIRONMENTAL P/M ASSEMBLY FREQUENCY RESPONSE (100K LOAD)

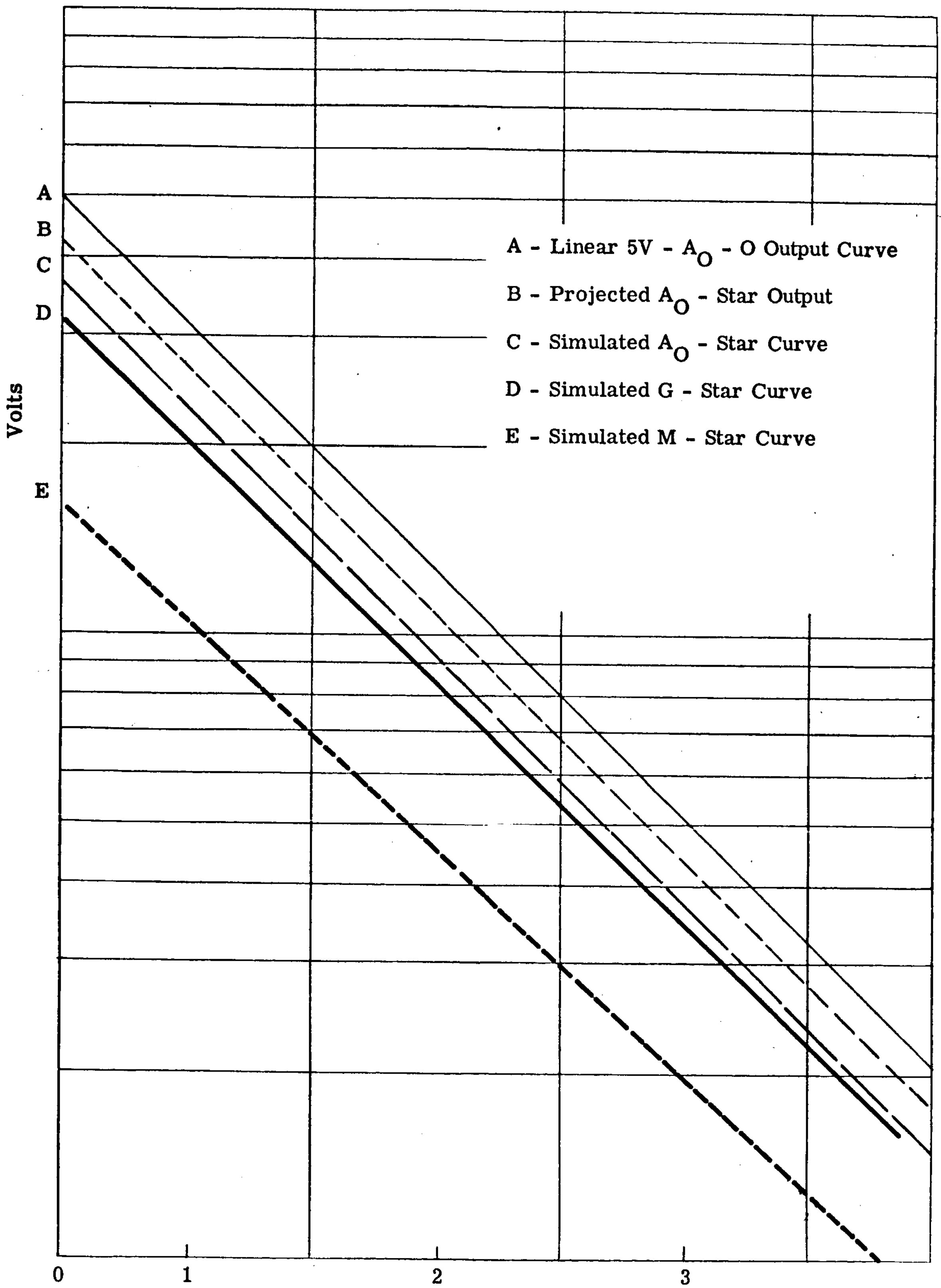


Figure 3 ACTUAL OUTPUT SPARE UNIT, QUALITY OPTICS WITH NEW RESISTOR

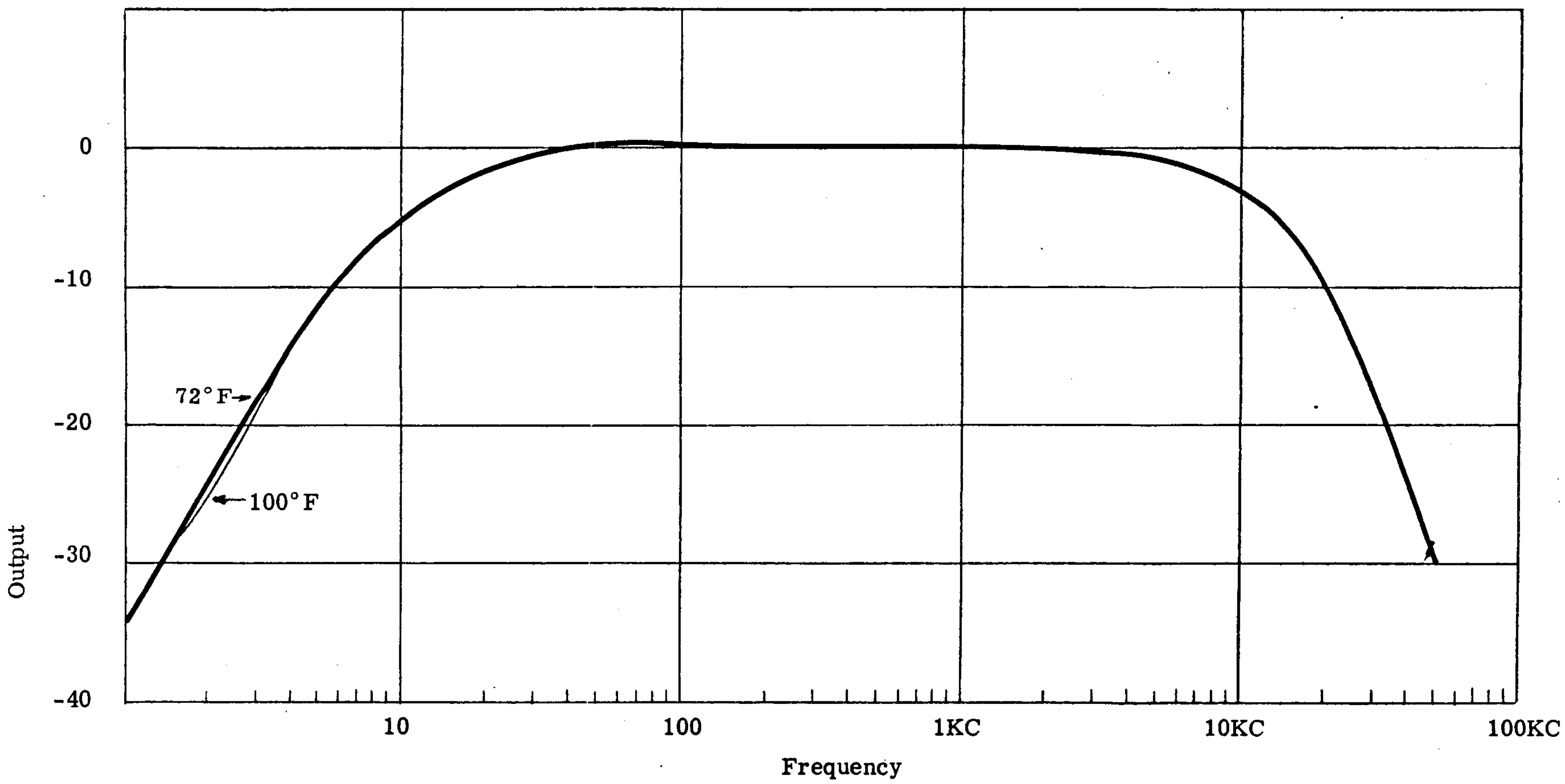


Figure 4 SPARE UNIT OPERATING TEMPERATURE FREQUENCY (85K LOAD)

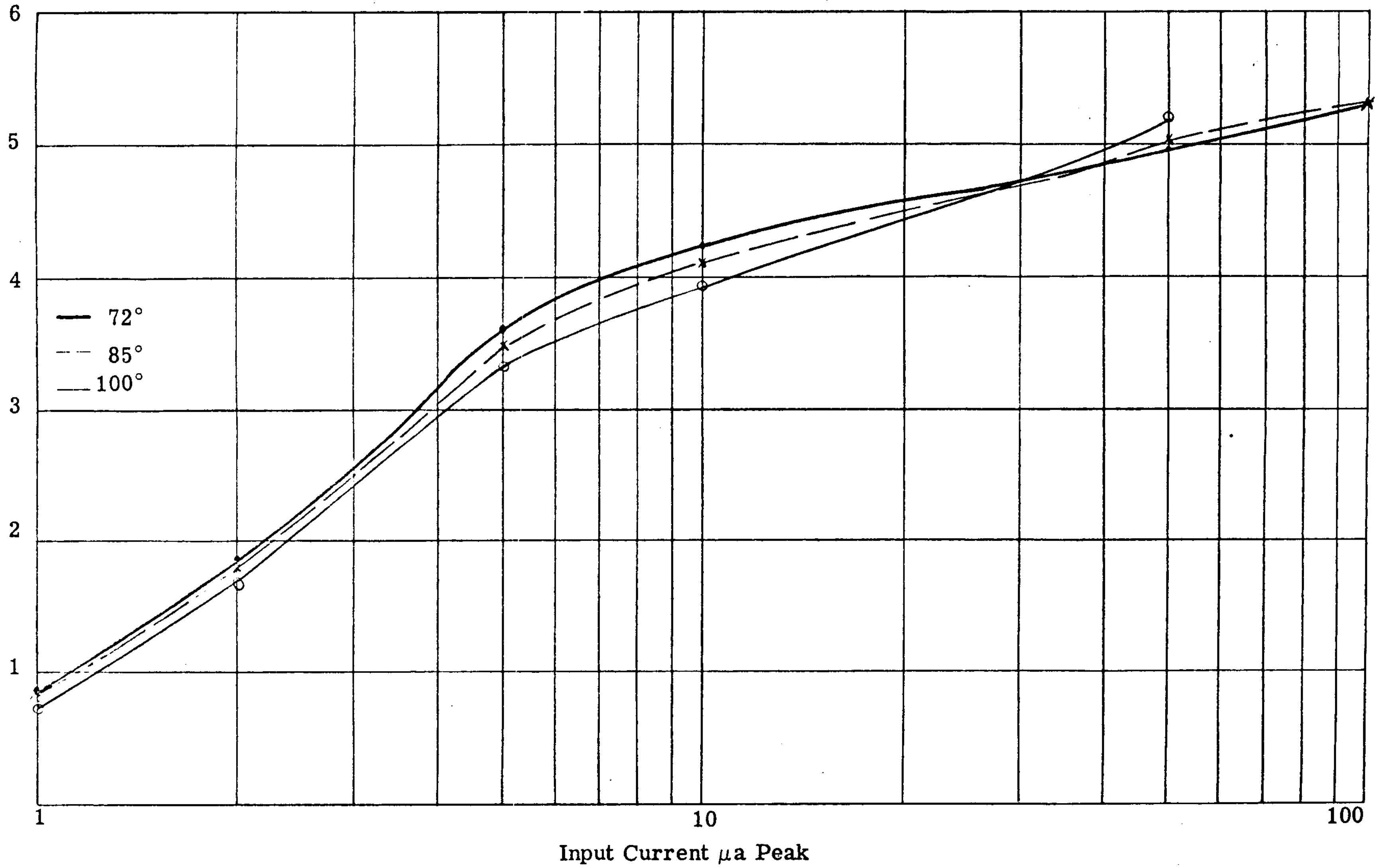


Figure 5 TELEMETRY AMPLIFIER GAIN LINEARITY WITH TEMPERATURE

APPENDIX G

PSST CALIBRATION REPORT

APPENDIX G

PSST CALIBRATION REPORT*

On the night of April 30 - May 1, 1964, pulse heights were measured for a number of (U, B, V) standard stars. The average pulse height for each observation was converted to the astronomical magnitude scale by the usual relation:

$$m = -2.5 \log_{10} \frac{I}{I_o} \qquad (1)$$

where I is the intensity (pulse height) and I_o is a reference intensity (1.0 volt signal).

On Saturday, May 2, these data were reduced at CEIR to outside the atmosphere by means of a standard 7090 extinction program in use at Harvard College Observatory. The equations of condition are of the form

$$\frac{1}{M} m_i = \frac{1}{M} m_{io} + A_o - A_1 (m_{io} - V), \qquad (2)$$

where M is the air mass of an observation of the i^{th} star, whose extra-atmospheric magnitude is m_{io}, and V is the visual magnitude of the star. The formal least-squares solution gave small negative values for both A_o and A_1 values which are not physically possible.

Since the RMS residual in equation (2) was very nearly 0.1 magnitude, and since the range of air mass for each star was generally small, it is not surprising that the data failed to give an adequate determination of atmospheric extinction.

---

* Letter by Dr. Andrew T. Young, 7 May 1964

However, at both sunset and moonrise on the evening of April 30, the extinction could be assessed visually, and was evidently quite small. Furthermore, the residuals from the least-squares solution did not display any systematic run with time. The night was clearly of good photometric quality. On such nights, the extinction is almost entirely due to Rayleigh scattering and is known from past experience to be about 0. 30 mag. for an effective wavelength near 4500 A.

The magnitudes of the stars were then computed from (2) using $A_o = 0.33$ and 0. 27 and $A_1 = 0$. The plots of $(m_{io} - V)$ vs. $(B - V)$ show about equal scatter. The slope of this relation determines the color equation of the instrument, and the zero point determines its sensitivity.

I believe the best values are given by

$$m_{io} = (-.60 \pm .05) + V + (.5 \pm .1)(B - V) \tag{3}$$

The signal output from a 0. 00 mag. AO star was therefore antilog$_{10} \frac{-.60}{-2.5}$ = 1. 74 volts. The estimated probable error of this figure is 5%, about equally divided between the extinction estimate and the scatter in the data.

Since the calibration was determined, the sensitivity of the amplifier has been increased by a factor of 2. 86; the signal from a 0. 00 mag. AO star will now be 4. 98 volts. The signal to be expected from a star of known magnitude V and color index (B - V) is now

$$\text{volts output} = \text{antilog}_{10}\ (0.697 - 0.4\,V - 0.2\,(B - V)).$$

The uncertainty in the predicted signal depends on the color of the star; it is given by

$$\% \text{ uncertainty} = - \quad 25 + 100\,(B - V)^2$$

Thus the uncertainty for B and A stars is 5%; for O and F stars, about 6 ½ %; for gKO stars, about 11%.

On the basis of the known temperature coefficients of photomultiplier tubes, a change in calibration on the order of 5% must be expected for a 10°F change in tube temperature. (The temperature during the calibration observations was kept between 80 and 85°F.) Since the temperature will not be controlled in actual operation, the calibration error is comparable to the accuracy the instrument can be expected to maintain in use.

Finally, since the uncertainty in stellar energy distributions in this wavelength range is about 10%, the calibration is probably more accurate than could have been achieved by calibration against a standard lamp.

Andrew T. Young
7 May 1964